THE WILEY TECHNICAL SERIES

FOR

VOCATIONAL AND INDUSTRIAL SCHOOLS

EDITED BY

JOSEPH M. JAMESON

GIRARD COLLEGE

For full announcement see list following index.

6-15-21

FIG. 1.—A modern farm barn.

Frontispiece

FARM BUILDINGS

BY

W. A. FOSTER, B.Sci. in Edu., B.Arch.

Farm Building Specialist, Agricultural Engineering Section, Iowa Agricultural Experiment Station, Member American Society of Agricultural Engineers

AND

DEANE G. CARTER, B.S. in A.E.

Formerly Associate Professor in Charge, Agricultural Engineering Department, North Carolina State College of Agriculture and Engineering, Associate Member American Society of Agricultural Engineers

NEW YORK

JOHN WILEY & SONS, Inc.

LONDON: CHAPMAN & HALL, LIMITED

1922

PRESS OF
BRAUNWORTH & CO.
BOOK MANUFACTURERS
BROOKLYN, N. Y.

PREFACE

THIS book treats of the location, planning, construction and repair of farm buildings. The material presented was collected from various sources by the authors; from their experience as farmers, experiment station workers and teachers. An effort has been made to group and present this material in an order which would make it practicable as a text book for college students, a reference for secondary schools and a source of information for the farmer.

The farm building problems have received more attention during the past decade than during the previous century. New types of buildings have been developed, new materials have come into general use and new constructions have replaced the old. Furthermore, the change of agricultural methods has affected farm building problems. For instance, expensive farm machinery must be protected from weather and live stock requires shelter by buildings formerly offered by timber.

An effort was made to pick out the practical and simple and present it in such a manner so it could be utilized by the student or farmer as a source of information and guide in building. While a course of study is not outlined, the teacher of farm building construction will find many problems which may be selected to fit any course.

The authors wish to express their appreciation to the many commercial organizations and the Iowa Agricultural Experiment Station which kindly allowed the use of illustrations; to Professor F. W. Ives, of Ohio State University, for reading the text and his constructive criticisms; to Professor Thomas E. French, Ohio State University, for his helpful suggestions, and to the editor for his assistance. It is hoped that any errors

which may occur will be brought to the attention of the authors and that they receive charitable consideration.

The authors will be glad to cooperate with teachers using the book as a text and to suggest courses of study.

W. A. Foster,
Deane G. Carter.

Ames, Iowa,
November 14, 1921.

ACKNOWLEDGMENTS

THE authors wish to express their appreciation to the following firms who cooperated in furnishing illustrative material:

American Radiator Company, Chicago, Illinois.
Adel Clay Products Company, Adel, Iowa.
Delco-Light Company, Dayton, Ohio.
James Manufacturing Company, Ft. Atkinson, Wisconsin.
Kewanee Private Utilities Company, Kewanee, Illinois.
King Ventilating Company, Owatonna, Minnesota.
Milwaukee Air Power Pump Company, Milwaukee, Wisconsin.
Moline Heat Company, Moline, Illinois.
Portland Cement Association, Chicago, Illinois.
Sanitary Manufacturing Company, Pittsburgh, Pennsylvania.
Somerville Stove Works, Somerville, New Jersey.
The Colt Company, New York City.
The Isko Company, Chicago, Illinois.
Western Silo Company, Des Moines, Iowa.
Williams Heater Company, Cincinnati, Ohio.
Wood Tire Silo Company, Sheboygan, Wisconsin.

TABLE OF CONTENTS

CHAPTER I

Introduction

CHAPTER II

The Dairy Barn

CHAPTER III

The Horse Barn

CHAPTER IV

Beef Cattle and Sheep Barns

CHAPTER V

General Purpose Barns

CHAPTER VI

Barn Equipment

CHAPTER VII

Essentials of Barns

CHAPTER VIII

Classification of Barns

CHAPTER IX

Barn Construction

CHAPTER X

Barn Framing

CHAPTER XI

Barn Ventilation

CHAPTER XII

Hog Houses

CHAPTER XIII

Hog House Sanitation

CHAPTER XIV

Poultry Houses

CHAPTER XV

Grain Storage Buildings

CHAPTER XVI

Silos

CHAPTER XVII

Implement and Machine Shelters

CHAPTER XVIII

Ice Houses

CHAPTER XIX

Minor Buildings

CHAPTER XX

Home-built Farm Equipment

CHAPTER XXI

Development of the Farm House

CHAPTER XXII

Planning the Farm House

CHAPTER XXIII

Farm House Construction

CHAPTER XXIV

The Tenant House

CHAPTER XXV

Farm Home Equipment

CHAPTER XXVI

Farmstead Planning

CHAPTER XXVII

Wood as a Building Material

CHAPTER XXVIII

Cement and Concrete

CHAPTER XXIX

Brick and Hollow Building Tile

CHAPTER XXX

Mechanics of Farm Buildings

CHAPTER XXXIV

Plan Drawing

CHAPTER XXXV

Rafter Framing and Cutting

CHAPTER XXXVI

Weights, Measures, and Formulas

CHAPTER XXXVII

Reference Table for Farm Building Design

FARM BUILDINGS

CHAPTER I

INTRODUCTION

FARM buildings in America have had their most rapid development in the years since 1910. With the exception of that pertaining to the farmhouse, there is little literature to be found on the subject.

The conditions surrounding the American farm have tended to hold back the development of good farm buildings. The early settlers in the timbered localities were primarily concerned with wresting a livelihood from their cleared fields, and bringing more land under the plow. For their buildings they used the material nearest at hand, and the log cabin and log barn became a part of the agricultural history of the country. The pioneer on the treeless prairie used the sod shanty, or the one-room board shack. The homesteaders were often people with little ready money, and their buildings were only the barest of shelters.

In many cases the early buildings still remain on the farm, to be used for storage, or for a few head of stock. The main buildings may have been entirely replaced, or remodeled to meet the changing needs of the farm family. The result is that many farmsteads give the impression of being poorly planned and run down. The material used in the early buildings was that most easily obtained. Size was looked upon as an index of the excellence of the barn or house. Wherever

timber was plentiful, the older barns were of the heavy timber frame. If lumber were scarce, the farm buildings were made too small, or of insufficient strength. Almost all of the older farm buildings show a lack of planning for economy of materials, labor saving, light, ventilation, and appearance.

Farm Capital Invested in Buildings.—The present value of farm buildings is probably in excess of 10 billion dollars. The census figures for 1910 give the value of all farm buildings as more than $6\frac{1}{3}$ billion dollars. This is an increase of 3 billions over the 1900 figures. Since the 1910 figures were collected, the most rapid development of the silo, modern barn, combined corn crib and granary, good hog house, and the improved farm home has taken place. All of these have contributed to an increasing valuation of farm structures.

Farm buildings represent 14.7 per cent of the value of all farm property. This is more than the combined value of implements, machinery, and livestock. On the average, the investment in buildings was $1773 for each farm in 1920.

Development in Past Decade.—Development in farm buildings in the years since 1910 has been rapid and continuous. Farming communities have become prosperous, and since the fundamental improvements of clearing, drainage, and tillage have been largely accomplished, more money is available for buildings. Land values have risen, and the owner is now justified in putting more improvements on the farm. Higher labor costs, higher prices for farm products, and scarcity of building materials have brought a realization of the need for buildings correctly designed for the purpose intended. Light and power plants, water systems, livestock equipment, grain-handling machinery, and the development of permanent building materials have all created a desire for better farm buildings, more home comforts, and labor-saving appliances.

Losses Due to Poor Buildings.—Preventable losses totaling hundreds of millions every year represent the price being paid by the American farmer for poorly planned or inadequate structures. The loss in depreciation of farm machinery

due to lack of proper housing is at least 100 million dollars each year, according to official estimates. Two hundred million more are lost by feeding rodents from the food storage houses of the country. Milk production from the 20 million dairy cows would be increased by several million pounds per day during the winter season, if all the cows were housed under modern conditions. Losses in the old-fashioned hog house, cattle shed, and barn take their toll of valuable livestock every year. In practically every type of farm structure losses

FIG. 2.—An attractive farm house.

may be found that could be prevented by good buildings. In most cases, either directly or indirectly, "we are paying for good buildings whether we have them or not."

Professional Farm Building Service.—The services of the architect and engineer are needed on the farm. In the past the field of the farming community has not attracted the architect, partly because the work of the city kept him busy, and partly because the farmer has not realized the need for specialized personal service. Much credit for the development of farm buildings is due to the professional services

rendered through the State experiment stations, agricultural colleges, trade associations, and manufacturers. These agencies have been instrumental in providing good plans, pointing out economies of construction, and proving the need of modern farm equipment.

At the present time there are a number of men devoting their entire time to personal service in promoting better buildings on the farm. There is no longer need to build any farm structure without the opportunity to study good plans and avoid the mistakes in building, which are sure to occur, if the work is done without forethought.

Everyone interested in the farm and farm building,

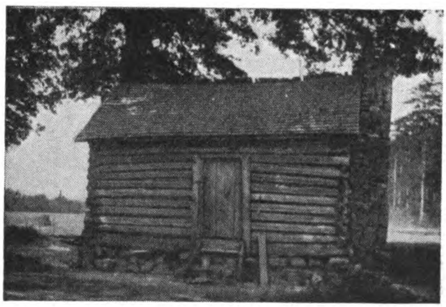


FIG. 3.—A Southern cabin.

whether farmer, student, builder, or manufacturer, should work toward the better appearance, more convenient plan, healthier stock, and better products, which characterize the well-planned group of farm buildings.

Purpose and Plan of Text.—It is the aim of the authors to collect in readily available form in this text the information on farm buildings that is necessary to a good understanding of the subject. Much good material relating to farm buildings has been published, but as it has come from so many different sources, it has not been possible for the average person to avail himself of complete information. Publications of experiment stations, building trade associations, and commercial com-

panies, have been drawn upon by the authors as well as their own experience in designing and in college teaching.

The arrangement of the material in the text groups the book into five divisions as follows: The Farm Barn; Other Farm Buildings; The Farm Home; General Subjects; and Useful Building Information. Where the book is used as text in courses of instruction, it will be necessary to include some laboratory work in drawing of building plans, and for that reason the plan, construction, essentials, etc., are given in the early chapters. After these points are covered, the problems of location, materials, strength, cost, and such subjects may be covered thoroughly. For the reader other than the student, the interest is first in the essentials of the separate buildings, and later, when the plans have been decided upon, the general subjects will be of more direct interest.

CHAPTER II

THE DAIRY BARN

THE dairy barn requires more careful planning than any other building on the farm except the farmhouse. As the dairy herd requires some work in the barn every day in the year, convenience of plan and proper equipment will reduce the amount of labor needed, while mistakes in any part of the plan will do more harm than in a less used building. The dairy barn is a factory where human food is produced, and for this reason the sanitary requirements of light, ventilation, drainage and cleanliness cannot be over-emphasized. The barn should be and often is as clean as many kitchens.

The authors believe that the best results can be secured by an original plan for each case, in which is embodied as many good features as possible. It is not possible fully to standardize complete plans with any degree of satisfaction, for each farm furnishes an individual problem. The items of stalls, mangers, gutters, alleys, and pens may be standardized and the suggestions given in the following paragraphs have been found to give the best results in many barns.

Location.—The dairy barn should be located with reference to the other buildings in the farmstead group, as discussed in Chapter XXVI. A study of existing buildings must be made before the exact location can be determined, and a study should be made of feed lots, pastures, windbreaks, and the contour of the ground. An open yard to the south is desirable. Sheds or wings connected to the main barn should be located with the idea of securing protection, without interfering with light and ventilation. The barn should be placed with the long axis north and south, in order to secure direct sunlight on the stalls for as much of the day as possible.

Ceiling Height.—Eight and one-half feet is perhaps the best ceiling height in the dairy stable. Ceilings below 8 feet afford too little headroom, and interfere with the correct lighting. More than 9 feet of headroom costs more, reduces the amount of hay storage above, and is difficult to keep warm in winter. The height is measured from the alley at the rear of the stalls to the under side of the joists. Stables of the monitor type, which give a ceiling height of 12 feet or more, and have windows in the upper part of the wall, should be avoided in cold climates.

Width.—The best width for the dairy barn is between 32 and 38 feet, providing for two rows of stalls lengthwise of

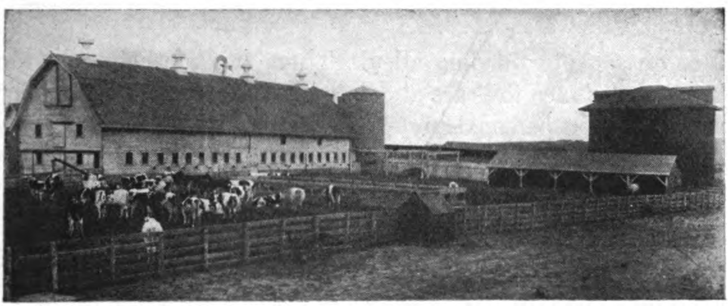


FIG. 4.—A modern dairy barn and yards.

the barn. A width of 34 or 36 feet works out to the best advantage in affording correct widths of alleys and stalls. However, the items making up the width of the barn may be varied somewhat from the standard dimensions to as much as 4 feet, more or less, than 34 feet, if necessary. Barns for more than two rows of stock are not recommended. The framing of the wide barns is heavier, and more difficult to construct, hence more expensive. Hay storage is more of a problem and the barn is difficult to light and ventilate.

Length.—The length of the diary barn depends entirely on the amount of stock to be housed, barns 150 feet or more in length being not uncommon. There is no definite relation

as regards appearance between the width and length of the barn. Large dairy plants are made in two or more units, connected in L or U shapes, forming a sheltered yard.

Facing the Stock.—Cows in stalls may face the outer wall, with a single cleaning alley in the center, or they may

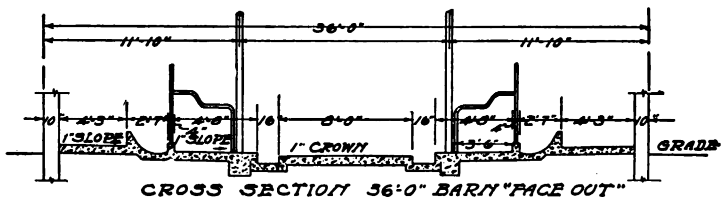


FIG. 5.—A cross-section of a 36-foot dairy barn—cows faced out.

face on a center feeding alley. These two methods of "face out" and "face in" are about equally favored by good dairymen, and the personal preference of the owner should be the deciding factor. A comparison of the advantages of the two facings follows:

Advantages of "face out" arrangement:
- Cleaning is done from one alley, direct to manure spreader, if desired.

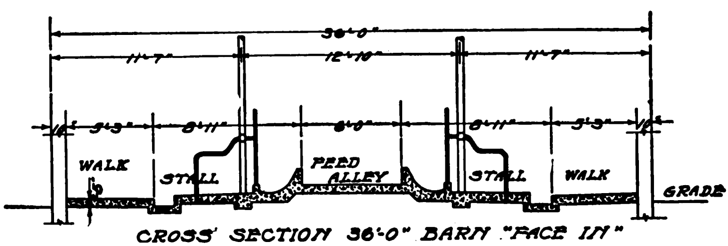


FIG. 6.—A cross-section of a 36-foot dairy barn—cows faced in.

- Three-fourths of the barn work is done behind the stock.
- Sunlight falls directly on the manger, and keeps the feeding compartments sanitary.
- Stock on display shows better from the rear.

It is not necessary to divide the herd at the door.
Box stalls may be arranged with less waste space.

Advantages of "face in" arrangement:

Cows are fed from one alley.
Feeding is done more often than milking and cleaning.
Sunlight on the gutter aids sanitation.
Better light for milking.
Entrance by two doors avoids danger from crowding.
Ventilating system can be installed to much better advantage.

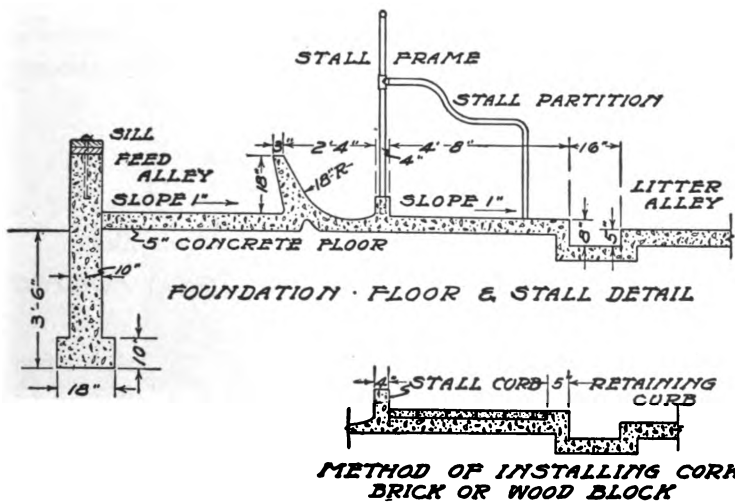


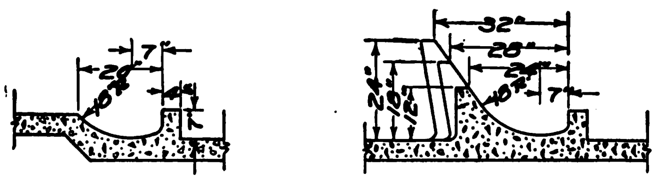
FIG. 7.—Details of dairy cow stalls.

Stalls.—Cow stalls are 3 feet 4 inches wide in a large number of the modern dairy barns, with varying widths of from 3 feet 2 inches to 3 feet 6 inches. The latter width is quite commonly taken as a standard. Very narrow stalls are inconvenient, and are not comfortable for the cow. Wide stalls allow the manure to be deposited on the standing platform.

An average length of stall platform from curb to gutter is 4 feet 8 inches, as this length will care for the average diary animal. There are several means for adjusting the length

of the platform to suit the needs of different cows. One of the most common is to use adjustable stanchions to align the cows on the gutter. Another method is to vary the length of the row by making the gutter at an angle with the curb, thus providing a graded length of platform. In large barns different sections of stalls may have standing platforms ranging from 4 feet 6 inches to 5 feet. In old barns it is often necessary to fit the stalls into a given space, in which case the above figures may be varied within narrow limits.

Manger.—The dairy manger should be permanent, sanitary, and easily cleaned. The width and height should be such that the cow will not throw feed out into the alley, yet not so large as to cause inconvenience in feeding. The manger



PROPOSED STANDARD MANGER FORMS

Fig. 8.—Standard mangers.

should be built so the cow may feed near a level with her feet, as in the pasture. Manufacturers have had standard mangers which met the above essentials, but some confusion has resulted due to slight differences in the measurements. The United States Department of Agriculture has recommended the following as the standard measurements for mangers:

Width, Inches	Height of Front, Inches
20	6
24	12
28	18
32	24

The shape of the bottom of the manger is formed by the arc of a circle between the front of the curb and the manger front. The radius of the arc is 18 inches, and is centered at a point 7 inches in front of the stall frame. (See Fig. 8.)

Concrete is the recommended material for the manger, as it is easily made to any desired shape, and is permanent and easily cleaned. The manger is made at the same time as the floor, and may be an integral part of it. If the cows are to be fed individually, there should be divisions between the mangers. These divisions are usually made of steel, and should be arranged to raise for easy cleaning of the manger. Steel mangers on a concrete base are sometimes used in place of concrete.

Curb.—The curb forms the rear of the manger, and serves to hold the stanchions and stall frame. Bolts, plates, or

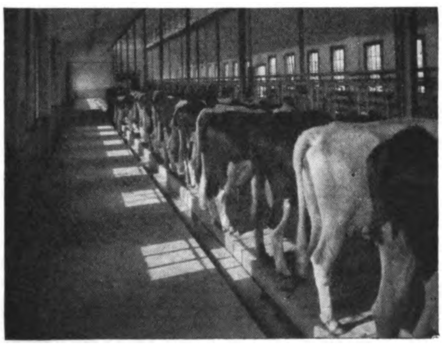


FIG. 9.—Cows in stanchions.

anchors are placed in the curb at the time the concrete is poured, and the equipment is bolted fast later. The curb is 6 inches high, and 4 to 6 inches wide. A rich mixture of concrete is necessary for the curb construction.

Gutter.—The purpose of the gutter is to promote sanitation by confining the manure below the level of the stall; by preventing spatter of liquid manure; and keeping the litter from being scattered over the entire floor. The width usually provided is 16 inches. On the stall side the depth is 7 or 8 inches, and on the alley side about 4 inches. The bottom of the gutter should be made level crosswise rather than sloping and the litter alley made about 3 inches lower than the platform,

There is, however, a slope lengthwise of the gutter, of about 1 inch in 25 feet for drainage.

Feed and Litter Alleys.—The feed alley should be from 5 to 6 feet wide, if the cows face the center of the barn. In the face-out arrangement the minimum width should be 3 feet 6 inches, and 4 feet is considered as about the best width. A center litter alley should be from 6 to 8 feet, and at least 4 feet 6 inches when the stock face the center. In case a driveway through the barn is desired, 8 feet is the minimum width between gutters or mangers. The best alley widths, in

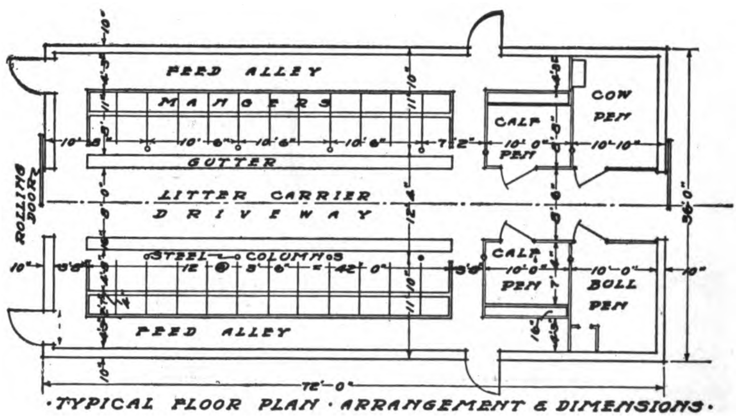


FIG. 10.—A floor plan of a dairy barn giving usual dimensions.

connection with the widths given above for stall, manger, curb, and gutter, can readily be secured in the common widths of 34 and 36 feet for the entire barn.

Cross alleys should be provided at intervals in the length of the barn, for crossing from side to center alleys; they should be 3 feet or more in width, and placed at frequent intervals, depending on the floor plan.

Box Stalls or Cow Pens.—Very few well-equipped barns are without one or more box stalls. For more than a half dozen cows the box stall is a necessity. At calving time or when an animal is sick, freedom of movement and careful

handling is possible only in such a stall. Cows on official test are often housed in a box stall for best yields. The box stall should be at least 8 feet each way, and is fitted with gate, feed box, and stanchion.

Bull Pen.—To keep the bull in best condition he must not be too closely confined, must be allowed to exercise, kept in sight of the herd, and yet be kept so he cannot harm the attendant. The pen must be strong and substantial, and should be 9 feet or larger each way, in order that the bull cannot brace himself across the pen. A low manger, heavy stanchion, and a safe gate constitute the necessary parts.

Calf Pens.—The calves should be housed in the dairy barn both for warmth and convenience. The main barn is likely to be better lighted and ventilated than a separate calf shed. The pen, at least 7 feet in the least dimension, should provide means for stanchioning each calf, so they may be fed individually. Stanchions about 20 inches apart along the front panel, a flat-bottom feed trough 16 inches wide, and metal shields between stanchions are essential.

Floors.—A dairy barn floor should be sanitary, permanent, easily cleaned, and comfortable for the cows. None of the materials used is ideal in every respect. Concrete, however, is the most generally satisfactory material, and its use is recommended. For the standing platform, wood blocks or cork brick are desirable. The materials used for dairy barn floors are dirt, wood, hollow tile, concrete, wood blocks, and cork brick.

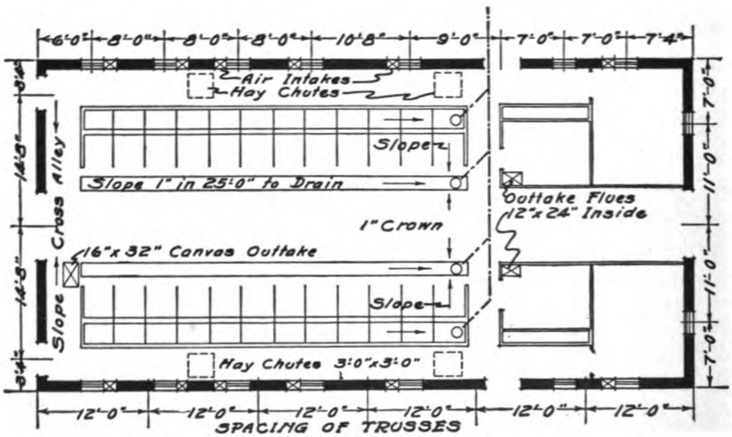
Dirt floors are cheap, and are suitable for cheap construction only. The dirt floor becomes fouled, tramped out of shape, and part of the dirt is carried out with the litter. When dirt floors are used it is essential that the manger and gutter, at least, be of some more permanent material.

Wood floors, which were formerly used almost entirely, are giving way to better material. Wood floors are expensive to build, harbor rodents, decay, and are unsanitary from every standpoint. They must be replaced every few years.

Hollow-tile floors are made by placing a layer of 4-inch or

5-inch hollow building tile on a sand cushion and covering with 2 inches of cement mortar. Defective tile may be used to reduce the cost. The advantage claimed for tile floors is that the air spaces in the tile tend to stop the passage of moisture and cold through the floor. The tile are not used in the floor of the driveway.

Concrete is the material recommended for average conditions. The cost is comparatively low, the material is readily adapted to the shape desired, and the resulting floor has all



·FLOOR PLAN SHOWING LOCATION OF DOOR·WINDOWS·
·DRAINS· HAY CHUTES·AND VENTILATING FLUES·

FIG. 11.—A floor plan of a dairy barn indicating location of hay chutes, ventilating flues, windows, etc.

the essentials except warmth. The construction is similar to sidewalks, and is discussed in Chapter XXVIII.

Wood blocks and cork brick are not intended for the whole floor, but only for the standing platform The object is to provide a warm, dry, resilient, and comfortable floor for the stall, and also one that is not slippery. These materials are laid on a concrete base. The wood blocks are creosoted to prevent decay, and are laid with asphalt joints to care for expansion. The cork brick are made from a mixture of cork

and asphalt, and give a very excellent floor. These materials are more expensive to install than the more common flooring materials, but especially for high producing dairies, and breeding stock, their use is justified. For the small or average barn, concrete with an abundance of bedding is satisfactory.

Drainage.—There should be a drain in the bottom of each manger and gutter, so placed that each outlet will care for from 25 to 30 feet of length. Special drains are necessary if the liquid manure is to be cared for through drains. The standing platform should slope 1 inch back toward the gutter. The litter alley should be sloped toward the gutter at the rate of about 1 inch in 4 feet. Feed alleys are given a slight pitch to one side, for thorough drainage. Gutter and manger bottoms should slope about 1 inch in 25 feet to a drain. Pens and box stalls are not usually provided with drains, but the pen floor should slope slightly toward the gate, for flushing.

Lighting.—Four square feet of glass, well placed, should be provided for each mature animal in the dairy barn. For pens, it is usual to allow 1 square foot of glass area for each 25 square feet of floor space. Light is essential for convenience in handling the work in the barn, for cow comfort, and sanitation. Double glazed sash or storm windows are desirable in the colder sections of the country.

Milk Room.—The milk room should not be included in the dairy barn, but should be planned as a separate structure, as discussed in Chapter XIX. When located inside the barn, the milk room is likely to be unsanitary, and where a steam boiler is used the fire risk is increased.

Feeding Conveniences.—A feed storage room is essential in connection with the dairy barn. Where cows are fed individually, space for mixing feeds and adding concentrates is needed. It is cheaper to carry the feed to the barn by the wagon load rather than by hand. The feed room should provide for at least two or three wagon loads of feed at one time and should, of course, be convenient to the stalls and the feeding alley. Overhead bins in the hay loft are economical, if a portable elevator is available.

The silo may be located at the side or end of the barn, in the most convenient position for easy feeding. A single silo should be located about 6 or 8 feet from the barn, and the space covered, to form a passage. Two silos when placed together should have a larger passage to the barn, and be so

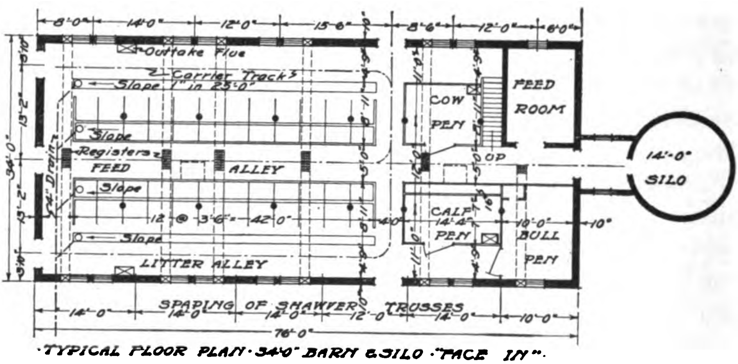


FIG. 12.—A floor plan of a typical dairy barn.

arranged that silage from either may be fed to the entire herd. The practice of placing the silo inside the barn is to be discouraged, on account of the additional cost and the inconvenience of filling.

Hay storage above the dairy stable is an economy, and

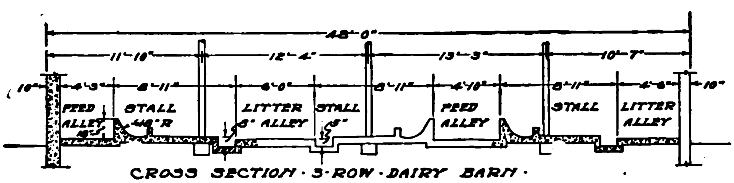


FIG. 13.—A cross-section of a wide dairy barn.

should be provided in every case, except where freedom from dust is demanded in the production of certified milk, or where a feeding barn is already available close at hand. Modern barns with average height walls and self-supporting roof

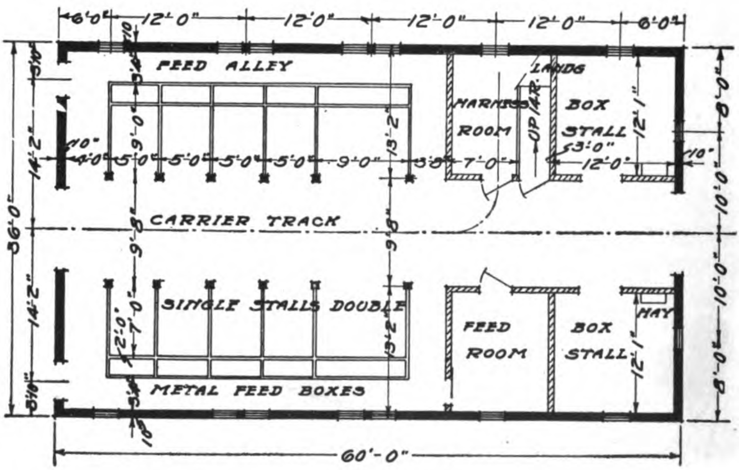
will hold approximately a ton of hay per foot of length of the barn. Equipment for handling hay should be provided in all cases.

Dairy Stable in the General Barn.—The points discussed above apply in particular to the dairy barn without other stock. Where ten or more cows are kept in the general purpose barn, the two row arrangement is the best, and the above principles apply. For a very few cows, feed rooms, box stalls, and like features must be worked out in connection with the balance of the plan.

CHAPTER III

THE HORSE BARN

THE horse barn on most farms is an item of expense for maintaining work animals, rather than a factory for farm products, for which reason it is likely to be slighted, in an



·FLOOR PLAN · HORSE BARN · 'FACE OUT'··

FIG. 14.—A floor plan of a typical horse barn.

attempt to keep the expense as low as possible. The results of poor housing for the horses are not apparent at once. However, if the items of efficiency, depreciation, labor, and feed saving are considered, the problem of the horse barn plan assumes more importance.

Essentials of the Horse Barn.—The horse barn requires in a general way the same essentials as the dairy barn. It

should be light, well ventilated, convenient for the attendant, and should provide for the comfort of the animals. The following items should be considered as relating especially to the horse barn plan: (1) location, (2) width, (3) ceiling height, (4) alleys, (5) standing stalls, (6) box stalls, (7) floors, (8) harness room, and (9) feed and hay storage.

Location.—It is important that the horse barn be located so that the work animals can be brought from the barn to the service drive or yard without passing through gates. The convenience in getting the horses to and from fields, and to the machine shed should be considered. The general points of location are considered in Chapter XXVI.

Width.—The two widths of 30 and 36 feet are the best

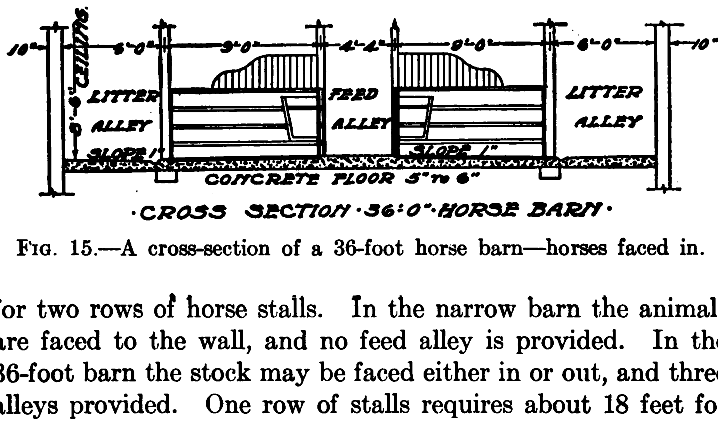


FIG. 15.—A cross-section of a 36-foot horse barn—horses faced in.

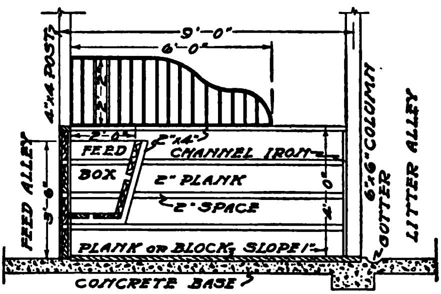
for two rows of horse stalls. In the narrow barn the animals are faced to the wall, and no feed alley is provided. In the 36-foot barn the stock may be faced either in or out, and three alleys provided. One row of stalls requires about 18 feet for alley, stall, manger, and walk.

Ceiling Height.—The distance from the floor to the under side of the ceiling joists should be at least 8 feet, and $8\frac{1}{2}$ or 9 feet is preferable. Low ceilings in the horse ba[illegible] are usually associated with dark, stuffy barn[illegible] there [illegible] also some danger of injury to the stoc[illegible] partitions and walls

Alleys.—Feed alleys are made [illegible]ed with wire mesh, and feet being the minimum for conve[illegible]rs. Permanent fixtures alley or driveway should be 10 feet w[illegible]uld be placed when the to avoid danger from kicking. If th[illegible]

center, the litter alley at the wall should be 5½ to 6 feet wide. Cross alleys for passage may be 3 or more feet wide if stock are to pass through.

Standing Stalls.—The standing stalls for work animals may be single or double. Most barns have both kinds, the work teams standing together, the single stalls being used for restless animals, driving or saddle stock or large horses. The standard single stall is 4 feet 6 inches wide from center to center of partition. In stalls much narrower than 4 feet 6 inches there is danger of the horse being caught fast when



CROSS SECTION HORSE STALL·

FIG. 16.—Details of a horse stall.

lying down. In wide stalls, the animal may be caught while attempting to turn around.

Double stalls range from 8 to 9 feet wide, with 8 feet as the most common. The length of both single and double stalls is 9 feet from the front of the manger to the rear of the stall partition. The top of the manger is 2 feet wide, and the standing platform is 7 feet long.

Box Stalls.—The box stall should be provided wherever more than three or four horses are kept. It is valuable for ever, if the items of mares at foaling time. The minimum saving are considered, ll is 10 feet each way, and a stall 12 by assumes more importan many plans the box stall may be so

Essentials of the serve as a double standing stall when in a general way the l should be equipped with a feed box

and manger of a type which takes up but little room, and has no projecting corners in the stall.

Stall Construction.—Stalls should be made tight, or practically so, to a height of about 4 feet. Above this height there should be a guard of wire mesh, or iron bars, or even wood, to a height of 2 feet, between the stalls. The manger is built up to a height of 4 feet on the alley side and 3½ feet on the stall side. The back of the manger should vary from 2 feet wide at the top to about 12 inches at the bottom, the latter being 16 inches from the floor. A small opening is left in the bottom through which dirt and chaff may be cleaned out.

The materials used in horse stall construction are wood,

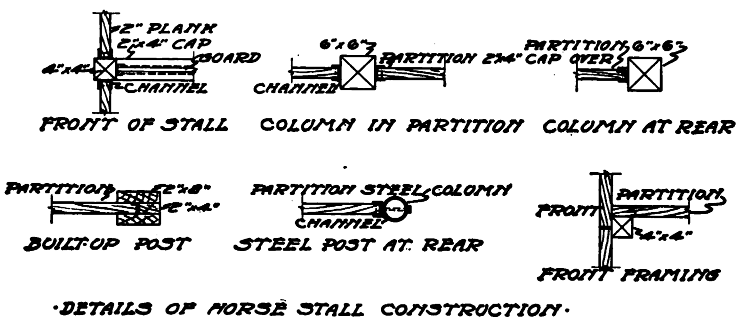


Fig. 17.—Details of horse stall construction.

concrete and steel. Wood is the most common material in use. The construction is principally of 2-inch planks. Two by 12-inch pieces are used for the partitions and manger, with 2 by 4-inch material for the framing. Supporting posts and braces may be of 4 by 4 or 6 by 6-inch lumber, as required for strength.

Concrete is an excellent material for the lower parts of the stall and manger, being permanent, sanitary, and a preventive of kicking and cribbing; it is somewhat more expensive than wood. The concrete partitions and walls should be 3 or 4 inches thick, reinforced with wire mesh, and the corners protected with channel bars. Permanent fixtures such as tie rings and harness hooks should be placed when the concrete is poured.

Steel construction for the horse stall is a recent development. Its principal use is in supplementing the other materials. Guard rails, feed boxes, hay racks, and mangers are

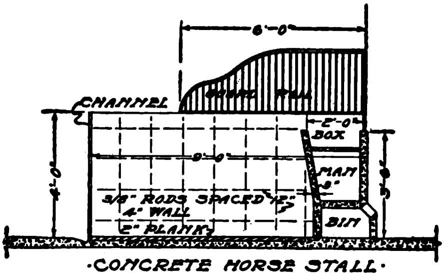


Fig. 18.—A concrete horse stall.

now made of iron and steel, and are very satisfactory. The steel is of good appearance, light, and easily cleaned.

Floors.—The most generally satisfactory floor for the horse barn is one of concrete overlaid with 2-inch plank. Concrete

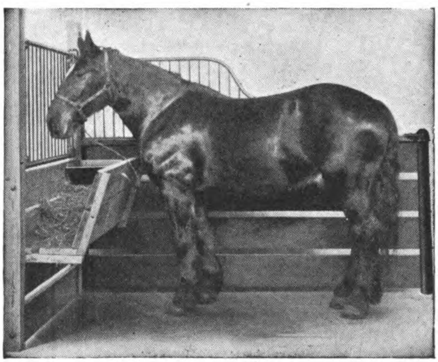


Fig. 19.—Showing horse in stall.

alone has the objection of being hard, and it is claimed by some users that the horses are injured if they stand for a considerable time on the concrete floor. Wood blocks and cork brick are used in the horse barn, and are considered better than plank.

The plank overlay in the stall is raised 2 inches above the alley floor. The stall floor is sloped 1 inch in its length toward the gutter. The gutter in the horse barn should

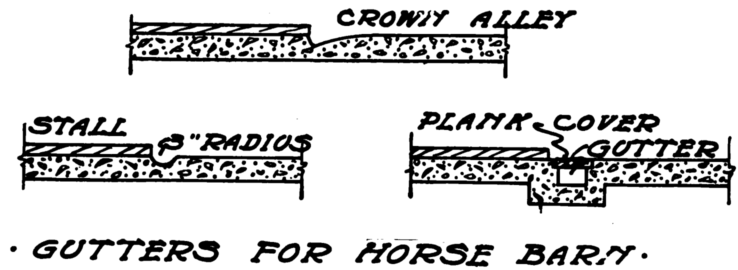


FIG. 20.—Typical gutters for horse barns.

consist of a slight depression in the floor, and not a distinct gutter. Another method of securing drainage is to make a gutter 8 inches deep and 6 inches wide, and cover it loosely with a plank set flush with the floor.

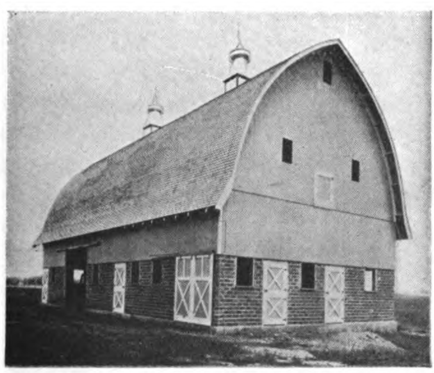


FIG. 21.—A Gothic roof horse barn.

Aside from the standing platform, the stable floor should be made entirely of concrete, as in the dairy barn.

Harness Room.—The principal purpose of the harness room is to provide a place for the storage of saddles, driving

harness, and parts which are not in daily use, since harness lasts longer when protected from the manure fumes. Equipment left around the stable is soon lost, fouled, or destroyed. Some farmers put the work harness in a special harness room every night, by means of carriers on the litter carrier track. The harness room should be about the length of the stall row, and from 5 to 8 feet wide. The walls should be made tight, and close-fitting doors provided.

Feed and Hay Storage.—Feed is required in the horse barn the year around, and the most feed is used in the busy seasons. For this reason, some provision should be made for the storage of several loads of feedstuffs at one time. Hay storage should be provided as in the dairy barn.

CHAPTER IV

BEEF CATTLE AND SHEEP BARNS

THE problem of the care, feed, and management of beef cattle and sheep is increasingly important on the farm, due in part to higher prices for farm land, the disappearance of grazing lands, and the greater demand for beef and mutton. More attention is now being paid to the production of young beef, and to breeding of pure bred stock, factors which call for more care and better management. The barn or shelter is one of the most important items in the handling of livestock.

Location.—The beef barns may be utilized as a windbreak for the other buildings, and to form a sheltered yard. A protected feeding yard to the south or east should be provided. Drainage of the barn and feed lots is important, especially as the stock is fed considerable roughage in the yards. Convenience to silos, cribs, and hay storage should be considered in locating the feeding barn, and provision should be made for entrance of wagons and spreaders without inconvenience.

Types of Beef Barns.—The requirements for a barn for feeding mature animals differs somewhat from those for baby beef. Breeding herds need a different sort of shelter than the fat stock. For the purpose of the present discussion, the authors have divided the subject into feeding barns, breeding barns, and barns for baby beef production. Barns for feeding stock are the most common, and will be discussed more fully here.

Essentials of Feeding Barns.—For successful feeding the beef barn must be planned for correct size, to provide feed storage, to shelter the stock in severe weather, and to provide for storing and handling manure.

Size.—The width of the feeding barn is limited by the framing necessary to support the roof, depending somewhat on the shape of the barn. For the self-supporting roof, the maximum width is about 42 feet, barns wider than this being difficult to light and ventilate properly. The best beef barns are from 36 to 42 feet wide, and the average space allowance in the pens is 40 square feet of floor for each animal. A baby

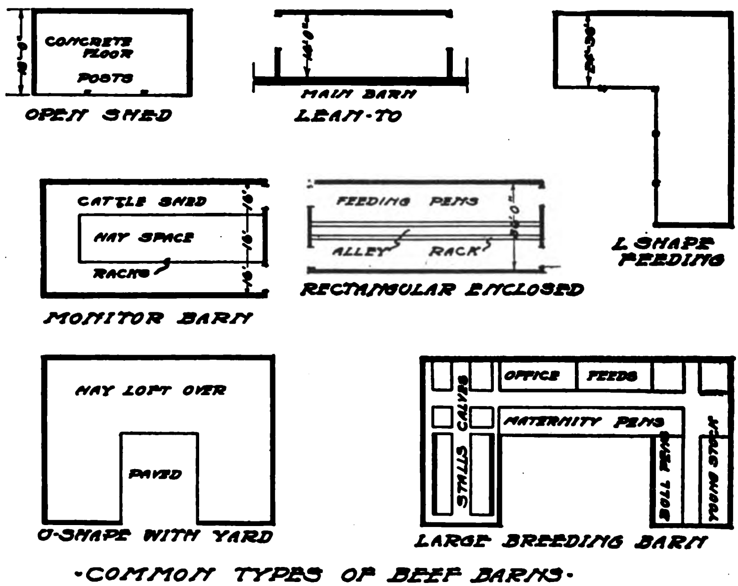


FIG. 22.—Common types of beef cattle barns.

beef requires about 35 square feet. In pens for less than ten head of stock, the space should be increased to 50 or more square feet. Two feet of rack or feed bunk is needed for each animal. The ceiling height should be at least 9 feet, to allow some accumulation of manure. Driveways should be 8 to 10 feet wide.

Feed Storage.—A majority of the feeding barns provide hay storage in the overhead loft, but in any event the supply of hay should be near at hand in sufficient amounts to avoid

long hauls in severe weather. Grain is usually stored in separate cribs, but they should be near at hand, and arranged so that wagon loads may be handled at one time, while the silo should also be located for ease of feeding directly into bunks. Much handling may be avoided by carriers from the silo to the troughs.

One ton of hay occupies about 500 cubic feet of space, a ton of silage 50 to 60 cubic feet, and one ton of shelled corn about 40 cubic feet. If the ration is figured, it is an easy matter to figure the amount of storage necessary.

Since the major part of the work with beef cattle is the feeding, and much time may be lost by careless arrangement,

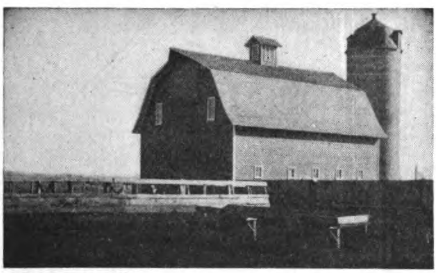


FIG. 23.—A small beef cattle barn in Iowa.

all bunks, racks, and storage rooms should be arranged for feeding from a wagon.

Shelter in Severe Weather.—The shelters in use for fattening stock range from the extremes of no protection whatever to well-bedded box stalls in a closed barn. Some quite successful feeders maintain that because of the protective covering of fat, the animal does not need any other shelter from the cold. While it is true that the fattening animal will stand more cold than the more delicate dairy cow, it is certain that some energy must be expended to maintain bodily warmth. Most feeders agree that some sort of shelter is necessary for most economical production. Shelter walls or windbreaks of trees help to provide a sheltered yard in which much of the

feeding may be done. Many of the feeding barns are closed on but three sides. If the barn is of the closed type, large doors are used, and these doors are not closed except in severe weather.

Handling of Manure.—Beef animals produce a considerable amount of manure, and many farmers in certain localities consider that the value of the manure offsets the labor in caring for the stock. Manure may be allowed to accumulate in the feeding barn and yard to a depth of 2 feet or more before it is hauled away. Concrete floors and pavements aid in handling the manure. It should be possible to drive a spreader to any

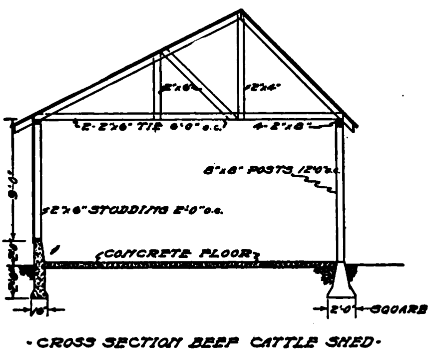


FIG. 24.—Cross-section of a cattle shed.

part of the feeding barn, to save excessive handling of the manure.

Sanitary Requirements.—The beef barn does not require as careful attention to the essentials of sanitation as the dairy barn. Drainage may be accomplished by allowing $\frac{1}{4}$-inch slope to the foot for concrete floors and paving, or 2 feet per hundred for unpaved yards. Unless the yards have good natural drainage, tile lines should be used to care for the surface water. Light in the barn should be provided for at the rate of 1 square foot of glass to 25 or 30 square feet of floor area. Controlled ventilation is desirable, but since the doors and windows will be open much of the time, sufficient air

circulation can usually be maintained without discomfort to the stock. In the colder parts of the country, however, metal ventilators and foul-air flues should be provided. Concrete should be used for floors, mangers, alley floors, and foundation walls. The foundation should be carried up to the height that the manure will be allowed to accumulate. In the low-cost beef barn dirt floors are commonly used for the pens.

Classes of Feeding Barns.—Although there are various shapes and kinds of barns used for feeding stock, the common ones may be classed as either open-shed barn, monitor barns, or closed barns.

The open-shed barn may be a single shed, closed on three

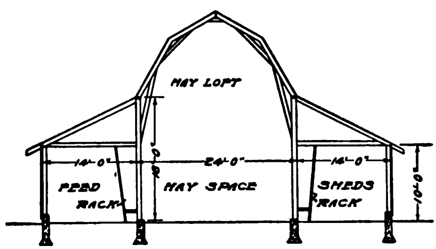


Fig. 25.—Cross-section of a monitor shaped feeding barn.

sides, and open to the south, or it may be L- or U-shaped, open on the yard. One-story sheds with one slope, gable, or "combination" roof are economical, and low in cost. Two-story shed barns are open along one side, but the loft and roof framing is similar to the two-story barns discussed elsewhere. Shed barns are often connected in the form of an L to the general purpose or dairy barn.

The monitor barn is made wider than the other types. It consists of a main part, 16 to 24 feet wide, for hay storage, and the hay space extends to the ground. On two or three sides of the barn are sheds for the stock, each 14 to 20 feet wide. Hay is fed into racks direct from the loft, and wide doors are provided at the ends of each shed.

The two-story closed barn for beef animals is the most modern as it harmonizes with the other barns, affords ample hay storage overhead, and can be built with a self-supporting roof. The hay can be fed through chutes, and silage is taken to the troughs by means of carriers. The feed alley is usually built higher than the pen floors, and the manure allowed to accumulate to a depth of 1 or 2 feet.

Barns for Breeding Stock.—Pure-bred animals raised for foundation stock require more careful handling and better housing than feeding stock. The breeding barn should be

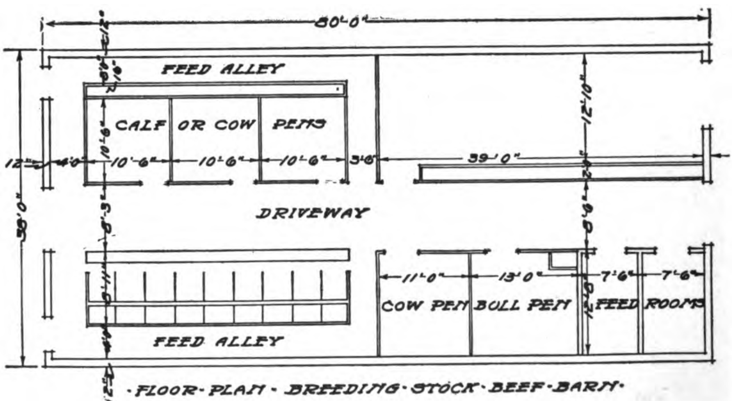


FIG. 26.—Floor plan of a beef cattle feeding barn.

well planned and of good appearance. Steel equipment is desirable. Careful attention is necessary to sanitation, to protect the health of the herd. The breeding barn should be a closed barn, with concrete floor, two-story construction, and pens for the various classes of stock. Stalls may be necessary for the cows with young calves. Cow, calf, and bull pens should be provided as in the dairy barn, and extra pens will be needed for growing stock—and young bulls. The problems of light and ventilation are similar to the problems in the dairy barn. For milking strains of beef cattle, the barn may well be a combination of dairy and beef barn, including the essentials of both, as discussed elsewhere.

Barns for Baby Beef.—On farms where the raising of calves and the production of young beef is practiced, there is need for a barn differing in some respects from the types discussed above. It must be closed for protection in winter

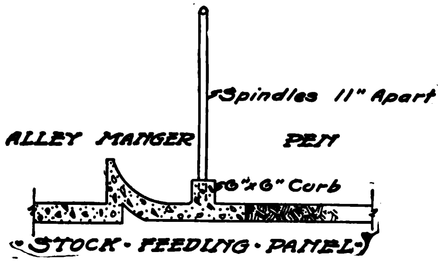


FIG. 27.—Cross-section of a stock feeding panel.

months. Calf pens should be provided for about eight calves to each twelve cows. Young stock or fattening pens may well be in the same barn. Thirty-five square feet of space should be provided for each fattening calf. Stalls should be provided for the cows in milk, and the stall row

FIG. 28.—A typical cattle barn of the Middle West.

located near to the calf pens. Baby beef barns where the calves are raised combine the essentials of the beef feeding pens, with the stall arrangement and calf pens of the dairy barn. The features of sanitation should be given careful attention in barns of this type.

Sheep Barns

Sheep raising is carried on under a wide variety of conditions in the various parts of the country, and it is not possible to present plans which will fit many conditions.

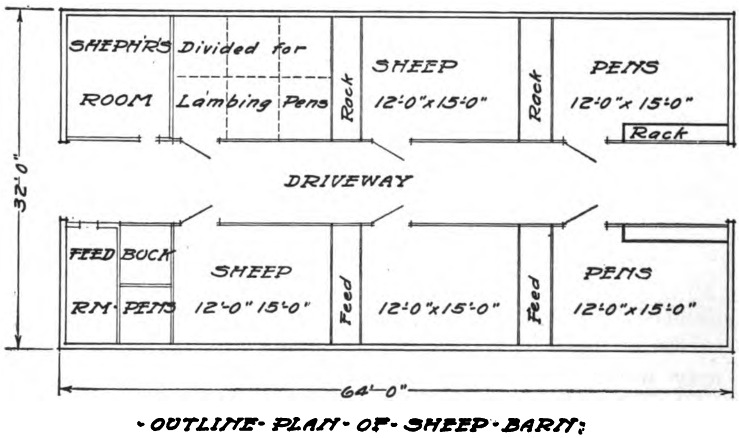


Fig. 29.—Plan of a sheep barn.

Essentials of Sheep Shelters.—Dryness of quarters is the most important essential in caring for sheep. Sheep do not require especially warm quarters, although direct drafts should be avoided. Sheep require shade in the summer season. Plenty of light is essential in the barn, for the health of the flock. One square foot of glass area for each 20 feet of floor space is recommended. Controlled ventilation is necessary in the colder parts of the country. Eight to 10 square inches of flue area should be provided for each sheep. Fresh air may be admitted through

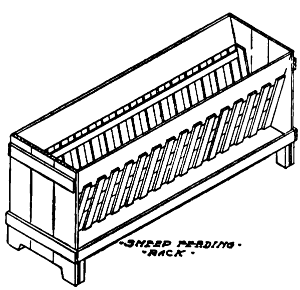


Fig. 30.—A good sheep feeding rack.

windows and doors in moderate weather, but care should be taken to avoid drafts.

Space Requirements.—Each animal requires approximately 15 square feet of floor space in pens for ten or more head. Rack and trough space of 15 to 18 inches per sheep is needed.

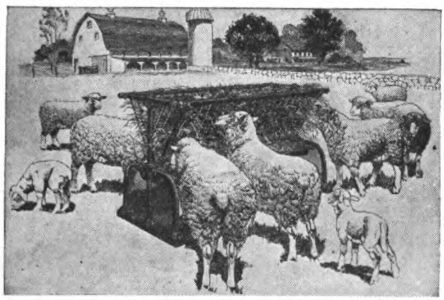


FIG. 31.—Sheep feeding rack.

Lambing pens are from 12 to 16 square feet in area, and a pen 4 by 4 feet is quite satisfactory. Separate pens are required for rams, and " creeps " should be provided for feeding young lambs separately. A room in the sheep barn, equipped with stove and medicines, serves as a hospital room at lambing time, and for the shepherd.

Types of Shelters.—Barns for the exclusive use of sheep are not common throughout the country. The cost should be low, as double walls and elaborate equipment are not necessary. The illustration (Fig. 29) shows a plan of a sheep barn. Usually the small flock will be housed in a shed, or part of the general barn. Except for the feeding equipment, it will be found that the requirements of sheep shelters are similar to those of the hog house.

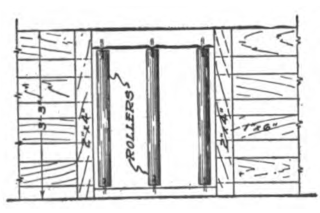


FIG. 32.—Detail of a roller lamb creep.

Equipment for Sheep Raising.—The most important piece of sheep-raising equipment is the rack for hay and grain.

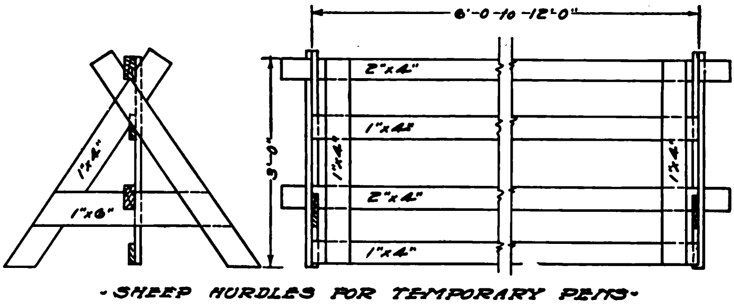


Fig. 33.—Details of sheep hurdles.

A good rack is shown in Figs. 30 and 31. The racks may serve as partitions in a large pen if made in the correct lengths.[1]

[1] Fig. 32 shows a roller creep for young lambs. Hurdles for making small pens, or for grazing are shown in the illustration. Farmer's bulletin 810 of the U. S. Department of Agriculture gives full plans and details of sheep shelters and equipment.

CHAPTER V

GENERAL-PURPOSE BARNS

In the foregoing chapters the requirements for special-purpose barns have been discussed. However, in the diversified farming regions of the United States, the dairy cows, horses, or beef cattle kept may not justify the expense of maintaining a separate barn for each. On such farms the general-purpose, or combination barn, providing for two or more kinds of stock, is the common type.

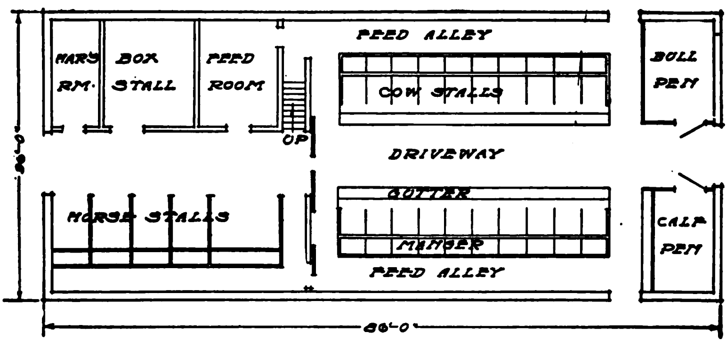
If only two or three cows are kept, and the barn is built primarily for horses, the barn is considered as a horse barn. One or two horses in a large dairy barn do not materially affect the plan and construction, and the barn is considered as a dairy barn. In discussing the general barn it may be assumed that the two or more classes of stock housed are of about equal importance.

Essentials of General Barns.—The essentials of the general barn are that it meet all legal requirements; each section should maintain the characteristics of the special-purpose barn; and the different classes of stock should be separated.

Legal Requirements.—In producing milk for certain cities and condensories, and in supplying certified milk there are housing rules and ordinances that must be observed. Inspectors are sent out to enforce the rules. In any case where milk is to be supplied under specified conditions, it is necessary to plan the barn and arrange the stock to meet these conditions, and produce sanitary products. In many cases all the rules may be met by separating the stock, installing steel equipment, ceiling the inside of the stable, and removing the manure to a covered pit. It is much less costly to pro-

vide for meeting the rules in the original plan than by expensive remodeling later.

Characteristics of each Section.—So far as possible the dairy stable, horse stable, and beef cattle pens, or sheep pens in the barn should retain all of the essentials as discussed for the separate barn. In the dairy regions of the country the new barns follow the essentials of the modern dairy barn, with light, ventilation, sanitation, and like essentials, although the barn may be used in part for horses or beef animals. The horse stable should also be planned with as much care as if it were an entire barn. In the items of appearance, economy,



•FLOOR PLAN GENERAL FARM BARN•

FIG. 34.—Floor plan of a typical general farm barn.

sanitation, and convenience, which are discussed later, the different parts of the barn often require similar treatment.

Separation of Stock.—The dairy cows and horses in the same barn should be separated by a tight wall, with doors in the alleys, which separation can best be accomplished by placing the horses in one end of the barn and the cows in the other. It is not good practice to put the cattle and horses opposite each other, in rows, with a common feed or litter alley. In large barns it may be best to place the cows in a separate wing or section of the barn. Feeding cattle require less care and may well be placed in an open shed, attached to the main barn.

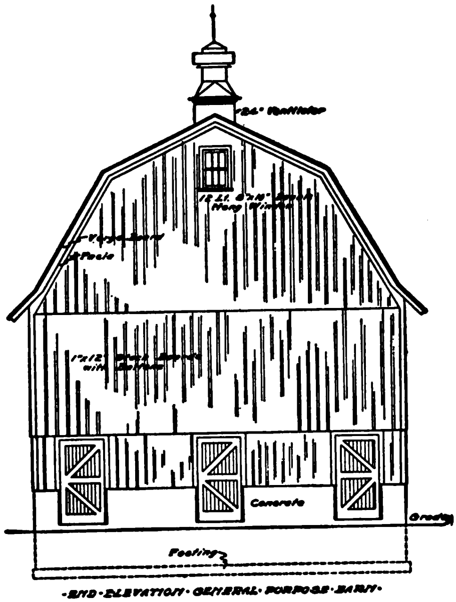


FIG. 35.—End elevation of a general-purpose farm barn.

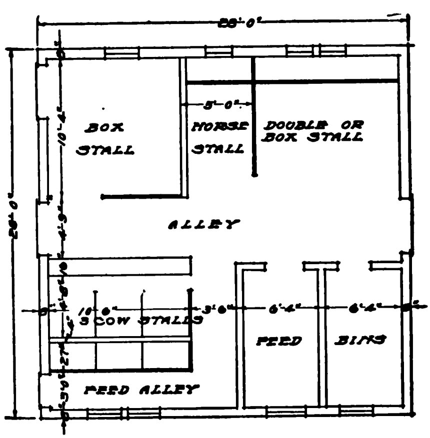


FIG. 36.—Floor plan of a small barn.

Width of Barn.—The width of the barn is determined by the needs of the class of stock requiring the most width for two rows of stock. Horses cannot be well provided for in less than 36 feet, with three alleys. If feed alleys are omitted in the horse stable, 30 feet is the correct width; however, two rows of cows need 34 feet of width for best spacing. Since each barn is a special problem in planning, it may be possible to secure a good plan for any width between 30 and 38 feet, by properly arranging feed room, box stalls, and pens.

Small Barns.—In some parts of the South, very little livestock is kept, and all classes of stock must be housed in one

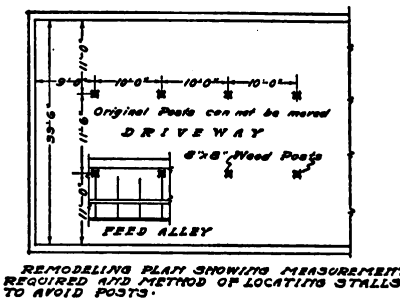


FIG. 37.—Remodeling plan for a barn.

small structure. Also, in small towns, there is need for barns to accommodate a few head of stock. The ideal plan of a general barn is one to provide for 12 or more cows, 6 horses, and 10 to 20 beef animals. The illustration (Fig. 36) shows a barn for a few head of stock.

Remodeling.—There is no more difficult problem in barn planning work than that of changing an existing barn to meet new conditions, or of installing new equipment in an old barn. A change in farming system or the need for more modern equipment makes remodeling desirable in many cases.

The first problem in the old barn is the tearing out of old stalls, floors, and fixtures. It is best to remove the entire lot of old material, except the supporting posts, and if the latter

can be moved, the new posts can be fitted into the plan. If the posts are located under a joint in the girder, it is then necessary to fit the equipment to the existing columns. Narrow alleys, dark corners, and inconvenient arrangement should all be remedied at the time the barn is remodeled. Windows.

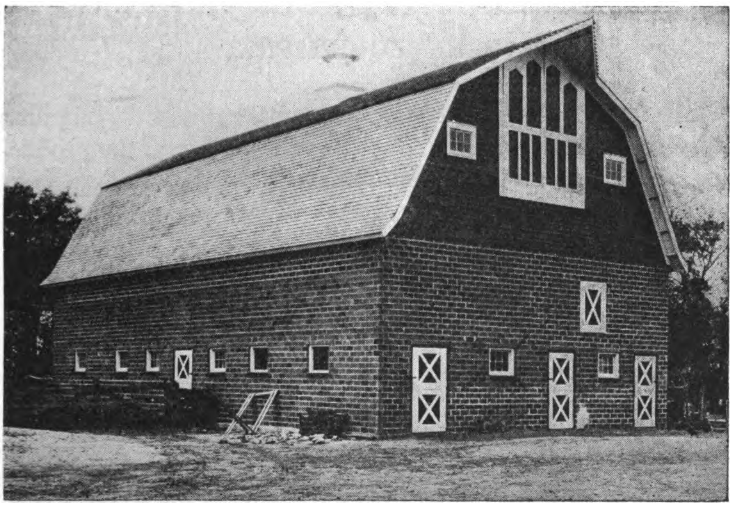


FIG. 38.—A good type of general-purpose barn.

ventilators, steel equipment, and concrete floors are the items most commonly included in the remodeled plan.

In measuring up an old barn for remodeling, it is essential that all measurements be exact and carefully noted, for equipment must be made especially to fit. It is often necessary to make stalls and alleys of unusual dimensions to fit into existing buildings.

CHAPTER VI

BARN EQUIPMENT

MODERN barn equipment is just as important in the handling of livestock as the grain binder and thresher are in the production of field crops. A few years ago the cost of modern barn

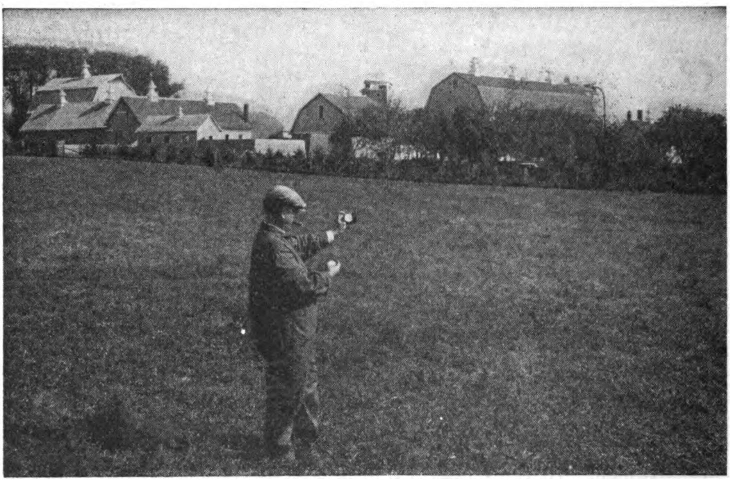


FIG. 39.—A group of well-equipped farm buildings.

equipment was considered prohibitive, and many men in a position to advise, recommended home-built, wooden fixtures rather than factory-made equipment.

The advantages of modern fixtures in the barn are labor saving; increased production; better sanitation; animal comfort; and the better appearance of the barn and the stock.

The cost of complete equipment will be from 15 to 20

per cent of the cost of the barn, and the more essential parts can be secured for less than this percentage. It is poor economy to cut on the cost of the fixtures, for by so doing much of the value of the entire building is lost.

No attempt will be made to discuss every feature of modern

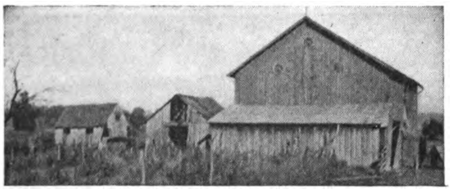


FIG. 40.—A neglected barn.

equipment. It is sufficient to discuss briefly the essential pieces of equipment that have replaced the wood stanchion, the wood cupola, common watering trough, and the wheelbarrow.

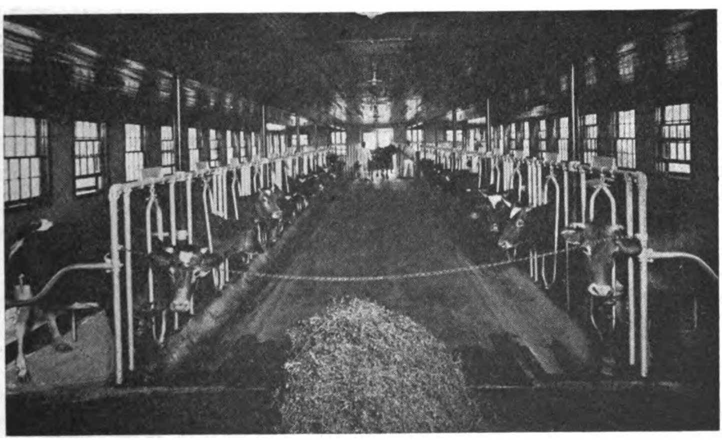


FIG. 41.—Interior of a modern dairy barn—cows here face in.

Stanchions.—The term stanchion is used to designate the neck piece which holds the cow. The essential features of the stanchion are that it hold the cow securely, be hung

flexibly, be strong, simple, and easily handled. Stanchions may be of wood or steel, or of steel with wood lining, to prevent wearing the hair from the animal's neck. They are made to fasten to either wood or steel frames, and may be adjusted for width of neck space, and aligned forward and back. Refinement in lock, hinge, and adjustment have been made by manufacturers in recent years.

Stall Partitions.—The standard material for stall partitions is $1\frac{5}{8}$-inch iron pipe, bent to shape in either a single or triple curve. The partition may be used in connection with either wood or steel frames. The rear of the partition is usually set in the concrete floor, though it may be fastened to a wood floor by means of a flange. The advantages of the partition are that it affords each cow a definite amount of space, prevents crowding, and protects the udders of the cows from being injured by neighboring animals. The usual dimensions is $3\frac{1}{2}$ feet high and $3\frac{1}{2}$ feet long.

Stalls.—Most new dairy barns have installations of complete stalls, consisting of stanchion, partition, stall frame, and the necessary fittings. The stall should be fastened to the curb in such a way that in case of breakage new parts can be put in without breaking the concrete. Bolts, plates, or anchors are preferred to having the stall post set in the concrete. Stalls may be purchased in standard widths, provided by all manufacturers, or in special widths, at no additional cost. Stalls for round barns must have the top rail bent to the curve of the stall row. The essentials of the complete stall are that it have tight fittings, ample head room, alignment, guide to direct the cow's head into the stanchion, and a proper method of fastening the stall to the curb.

Mangers.—The manger usually recommended is the concrete manger as discussed in Chapter II. For feeding individually the manger division is desirable. They are made of heavy galvanized steel, cut to the shape of the manger, the divisions being made to raise, for cleaning the manger. Complete steel mangers are made to set on a concrete base; they are built in sections of four or five mangers, held in place

by a spring, which also holds the manger in the raised position. The manger parts of steel should be of heavy gauge, galvanized steel, and firmly braced with bar iron. Manger divisions in the concrete manger are considered best.

Pens and Box Stalls.—Pens are always made in special sizes to fit the available space, and are fitted with the necessary gates, mangers, feed boxes, and stanchions. Steel pens for all classes of stock are preferable to wood, because of the better appearance, light, sanitation, and strength. Pens are made in panels, and are anchored to the concrete curb at intervals of 4 to 6 feet. The paneling is made from iron pipe or steel tubing, reinforced at corners, and at intervals in the panel with

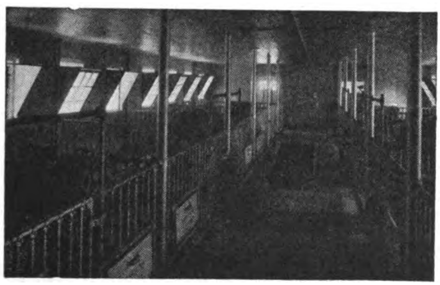


Fig. 42.—Metal box stalls and pens.

extra heavy posts. Dust-proof fittings, smooth surfaces, and rigid construction are necessary. Curbing for dairy pens is made 6 inches wide and 6 inches high.

Watering Cups.—Investigation among a large number of users indicate that the use of a watering system will increase the production of milk 2 to 3 pounds per day in the winter season over the common methods of watering. Some dairymen state that they prefer the cups to any other piece of equipment. High-producing cows will drink as much as 200 pounds of water per day. There are two types of watering systems for the dairy barn, the gravity and pressure systems, the former outfit requiring a head of water of only a few feet. The level in all the cups is maintained by gravity and regulated by a

float valve in a small supply tank. The pressure system has a valve in each cup, which is opened as the animal drinks, water being supplied under pressure to each stall. The advantage of the gravity system is its simplicity and ease of handling. In the pressure system fresher water is supplied and no regulating tank is necessary.

Litter and Feed Carriers.—Farmers have realized the labor-saving features of litter- and feed-carrying machinery, and most new barns provide for their installation. The trolley outfits consist of overhead track installation throughout

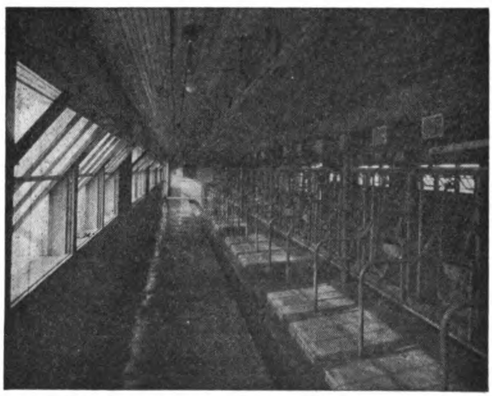


Fig. 43.—Showing stalls with individual drinking cup equipment.

the litter and feed alleys, and to manure pit and silo. By means of the carriers, only one handling of the feed and manure is necessary. With the litter carrier the manure is likely to be taken directly to the spreader, or at least farther from the barn, and better sanitation results.

The litter carriers in common use are of three types: the small outfit with rod track, the combination type, and the solid-track carrier. The rod outfits are recommended for small barns and low-cost installations. The action of the carrier is automatic, as it can be given a push at the door, and will dump and return to the barn. The combination

carriers have a solid track inside the barn, and rod track in the yard, combining the raising and lowering features with the automatic action in dumping. The solid-track outfit is recommended for all large barns. This carrier is not automatic, but is more convenient to handle in the barn, and has a greater capacity. The small carriers have a capacity of 4 bushels, the combination from 5 to 6 bushels, and the solid-track carriers hold from 10 to 12 bushels of manure.

The carrier tubs should be made of heavy, galvanized steel, well braced. The hoist should be easy working and positive. The track should be made to carry a heavy load,

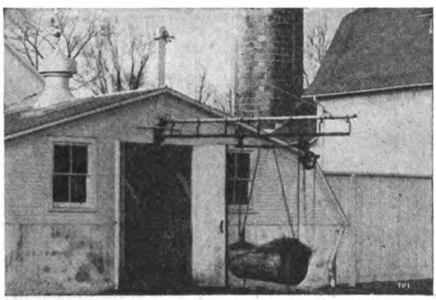


Fig. 44.—A litter carrier from a hog pen.

and is usually fastened at every joist. The track should be kept level, and set to allow the wheels to clear all obstructions.

The methods of supporting the track in the yard are wood posts, steel posts, steel arches, and swinging boom. The cost is in the order given. The crane or boom has the advantage in that it can be turned through a large angle, or against the barn, leaving the yard clear. Care should be taken not to obstruct a necessary drive with the posts and braces.

Feed carriers are made on the same general principles as the litter carriers, and operate on the same type of track. The usual capacity is 12 to 15 bushels of silage or grain. Feed carts or trucks are less expensive, and can be taken to any part of the barn, without track. Some feed trucks are

made to run on the floor and are equipped with rubber tires and roller bearings.

Special carriers are made for farm buildings for a variety of purposes, among which are harness carriers, milk-can carriers, swill carriers, and hoists for machinery or other heavy objects.

Ventilators.—The objects and principles of ventilation are discussed in Chapter XI. Metal cupolas are preferable to wood, on account of permanence, appearance, and efficiency. The metal ventilators on the market aid the outflow of foul air, and prevent the entrance of rain and snow; most of them are bird proof.

Window shields, intake registers, and adjusters are neces-

FIG. 45.—A group of modern farm buildings.

sary parts of the ventilating system, and good ones can be purchased. There is also on the market a complete ventilating system, consisting of fresh- and foul-air flues, registers, and cupolas.

Horse Barn Equipment.—The special fixtures for the horse barn include harness carriers, harness hooks, feed boxes, hay racks, box stalls, and guard rails. In addition to these items the usual carrier and ventilator equipment is needed.

The advantages of metal equipment over wood in the horse barn are, appearance, cleanliness, better sanitary features, and greater permanency. Box stalls of steel are usually made of concrete to a height of about 4 feet, and

paneling placed above the concrete base. The stalls may be of wood or concrete, as discussed in Chapter III, and are topped by a guard rail 24 or 26 inches high; the rails are about 6 feet long, and made with an ogee curve at the rear.

Feeding Barn Equipment.—At one time the first cost of barn equipment was considered prohibitive even for dairy

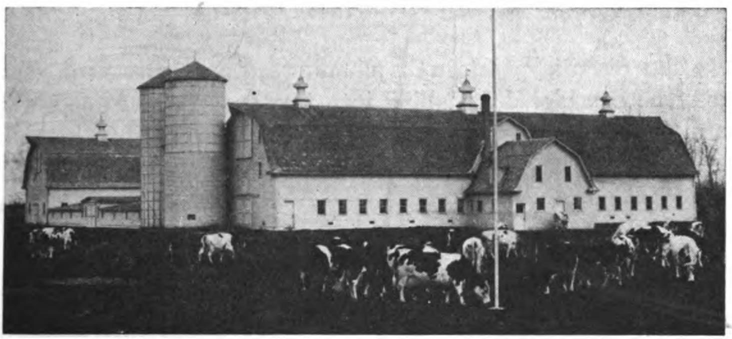


FIG. 46.—A large dairy plan.

herds. At the present time, not only most dairy barns, but many feeding barns are being completely equipped. For pure-bred stock, and breeding herds of cattle, sheep, and hogs the use of steel pens and other equipment is increasing. The principal material is the paneling used for cow, calf, bull, hog, and sheep pens. Stock racks, feeding troughs and removable panels are also being used.

CHAPTER VII

ESSENTIALS OF BARNS

THE essential points in the planning and construction of barns may be considered as falling into two groups. In one group are the essential points of the special-purpose barn to make it serve that special purpose. There is another group of essentials that are fundamental, and should characterize every barn, no matter what the purpose. It is the purpose of this chapter to discuss these general points.

Four Necessary Features.—All good barns have four features, without which they fail to become either ideal or even good barns for the practical farmer. They are, appearance, sanitation, convenience, and economy of construction. The practical man might neglect the feature of appearance, and still make the barn pay well on the investment. Barns that were unsanitary in every respect have produced products that passed high tests, due to a vast amount of labor. If the barn is not convenient the cost of additional labor will offset many times the cost of changing the plan. The rich man who farms as a pastime and who spends thousands of dollars per animal to secure a fine barn may be repaid in satisfaction, but he will realize no interest on his investment. Most assuredly, if all four of these essentials were not considered, the barn might well be torn down.

Appearance.—A building of good appearance does not cost any more to build than an ugly structure. If the best ideas of window location, ventilation, sanitation, and proportion are carried out, the only additional cost of a good appearance is some forethought in planning.

With the exception of the farm-house, the barn is the most

expensive building, and has the most prominent place in the farmstead group. As we learn to build with permanent materials and properly care for our farm buildings the barn will last for fifty to sixty years, or even for a century. The additional cost for good appearance, if there should be any cost, will amount to a small sum when distributed over the life

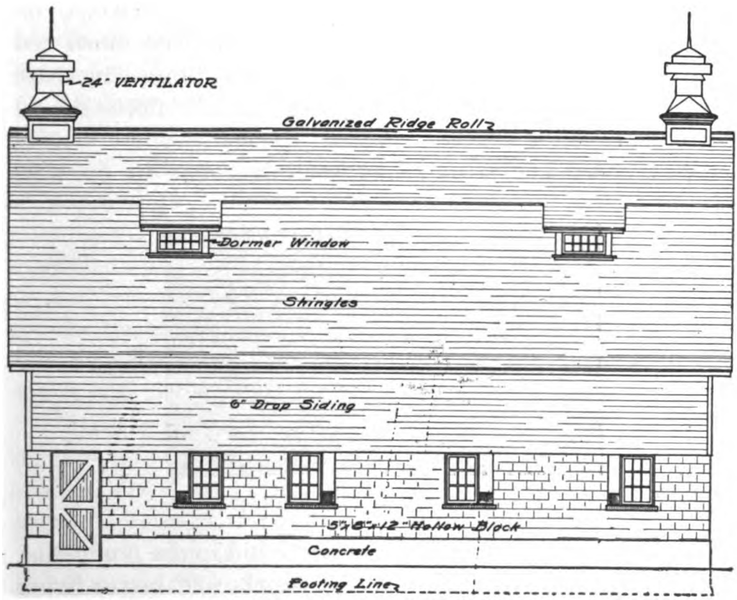


FIG. 47.—Side elevation of a typical small dairy barn.

of the structure. The selling value of the farm with attractive barns will often return the extra cost many times over.

For good appearance, the tops of all doors and windows in the first story should be on the level. Large windows, possibly in groups of two or three, are better than small single windows. Dormer windows often serve to break up large space of roof, and they light the loft as well. The roof should be in the proper shape and proportions—a point fully

considered elsewhere. The projection of the eaves, or the "overhang," should be in proportion to the size of the building.

There are several building materials which might be combined to enhance the appearance of the barn. Shingles, stucco, and lap siding, while not generally used as a barn covering, might well be used to advantage in many cases.

Paint on farm buildings is primarily for the protection of the wood. Careful selection of harmonious colors would do much to improve the appearance, however. Too much red paint does not add to the farmstead. At all times large bare surfaces, odd roof shapes, and "gingerbread" effects should be avoided.

Sanitation.—The essential of sanitation has to do with

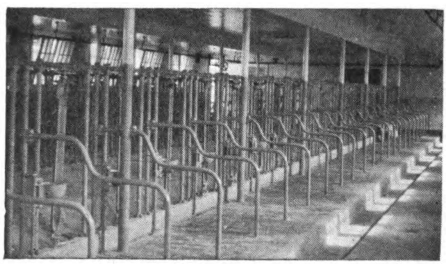


Fig. 48.—Interior of a small sanitary barn.

all points of plan and construction which aid in the production of better, cleaner products, healthier stock, and better living conditions. Sanitary laws have been enforced by many communities in an effort to secure better products. The higher prices, labor saving, and like results have led many farmers to build sanitary barns of their own accord as sanitation is the best preventive of transmittible diseases such as tuberculosis, cholera, and typhoid. The items of lighting, ventilation, drainage, modern equipment, and smooth surfaces are all considered elsewhere in the text.

Convenience.—There is no need to advance reasons as to why the barn should be made convenient. Scarcity and high prices for labor compel convenience of plan for handling

the work. On every farm there is need for many hours of barn work each month, and even small mistakes will cause considerable extra work. In almost every case a careful study of the proposed plan is all that is needed to secure convenience.

Harness rooms, silo location, width of alleys, location of doors, and arrangement of stall rows all have an influence in the convenience of the plan. One of the best pieces of advice to secure a convenient barn is to "build the barn on paper first."

Economy of Construction.—Economy of construction consists in building for the purpose for which the structure is intended. For the production of certified milk, the owner is justified in building a high-priced barn, with expensive equipment. The breeder of fancy stock will soon pay for a good barn by the increased selling price of animals in good health, and well shown. The feeder of range stock cares only for shelter, and an expensive barn would not yield additional returns. The Southern tenant who has only one cow, a mule, and a hog has no need for more than a mere shelter.

An expensive building is good economy if it is for the purpose of demonstrating good methods or of selling good stock. The type of farming and the value of the products help to determine the amount of the investment.

A good plan of the barn will help to keep its cost down. Framing can be reduced to a point consistent with strength; permanent materials may help to lower the cost when considered over a period of years; available materials mean less freight, shorter hauls, and lower prices, when compared to material that must be shipped a long distance. The width of the barn and the spacing of trusses and girders should be such that standard sizes of lumber may be used. Stock lengths and common sizes of lumber are cheaper than special material. Stock sizes of doors and windows are usually just as good as special sizes, and cost less.

Undesirable Uses of Barns.—In some parts of the country there is little need for a barn to shelter only a few head of

stock on the farm; and poultry, hogs, farm machines, and feeds are all placed in the same building. This practice should be discouraged in most cases. For housing machinery, tractors, and automobiles, a separate building is always to be recommended, as the fumes from the manure have a bad effect on the finish of the machines. The presence of gasoline and oils, and the operation of an engine in the barn is a dangerous fire risk, and insurance companies seriously object to the practice. The concentration of a large amount of stock, feed and machinery in one building would cause a serious loss in case of fire. Farm poultry in the barn is another practice that should be discouraged. Few flocks are entirely free from vermin, and for that reason should be kept away from the stock. Eggs are destroyed, chickens are killed by the stock, and droppings are scattered about the barn.

Common Features of Barns.—Every barn, regardless of purpose, has certain problems in common with other barns which are worthy of consideration. Among them are doors, windows, stairs, and hay chutes.

Doors.—Doorways through which stock must pass should be made at least 4 feet wide; feed-alley doors are made as narrow as 3 feet 6 inches; driveway doors should be 8 feet wide to allow the passage of wagon or spreader. The height of doors in the first story should be from 7 feet 8 inches to 8 feet 6 inches. The exact height will depend on the ceiling height, as the door frame should be built directly under the second floor joists. Doors for loaded hay wagons should have a height of 12 feet or more, and a width of 10 feet. Hay doors through which the hay is taken by means of forks or slings are made 10 feet wide by 12 feet high. Doors for hand pitching of hay should be at least 3 by 4 feet. Doors through which grain is to be shoveled are made 2½ by 3 feet.

For openings of 4 feet or less the doors should be hinged, as the hinged door can be better fitted, and is less expensive. The hinged door may be made in two sections, so the top half can be opened for ventilation. Sliding doors are more generally used for wide openings, as the hinged door more

than 4 feet across tends to sag, and is hard to handle in windy weather. Well-protected, bird-proof track, and substantial hangers are desirable with the sliding doors.

The best method of making hay doors is to divide the door in the center and slide it outward and downward, parallel with the roof slope; it is counterbalanced by weights. Another method of fastening the hay door is to hinge it at the bottom, a style susceptible of being broken by the wind. A third method is to counterbalance the door with weights and slide

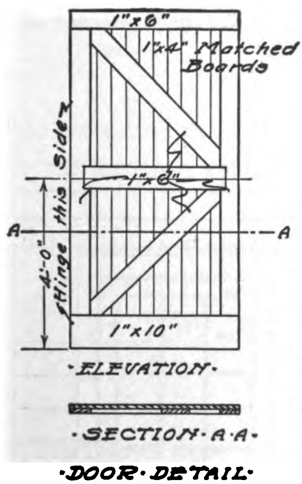


FIG. 49.—Detail of small barn door.

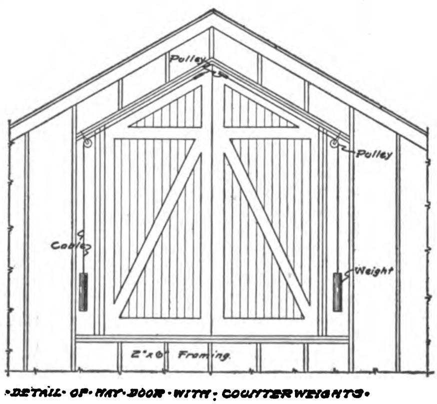


FIG. 50.—Detail of hay door for barn—view from inside.

it straight downward in a groove. In this case there is likely to be trouble due to warping.

Windows.—Probably the best type of window for all barns is the single-sash window, hinged or grooved at the bottom, and opening inward from the top. The common size is a 9-light sash, three panes wide and three high. The glass size is from 8 by 12 inches to 9 by 14 inches. This gives a sash approximately 2 feet 6 inches wide and 4 feet long. A comparatively high window is more efficient than a low one,

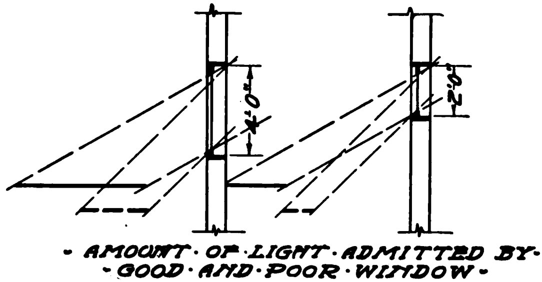


FIG. 51.—Illustrating influence of height of window upon amount of direct light admitted.

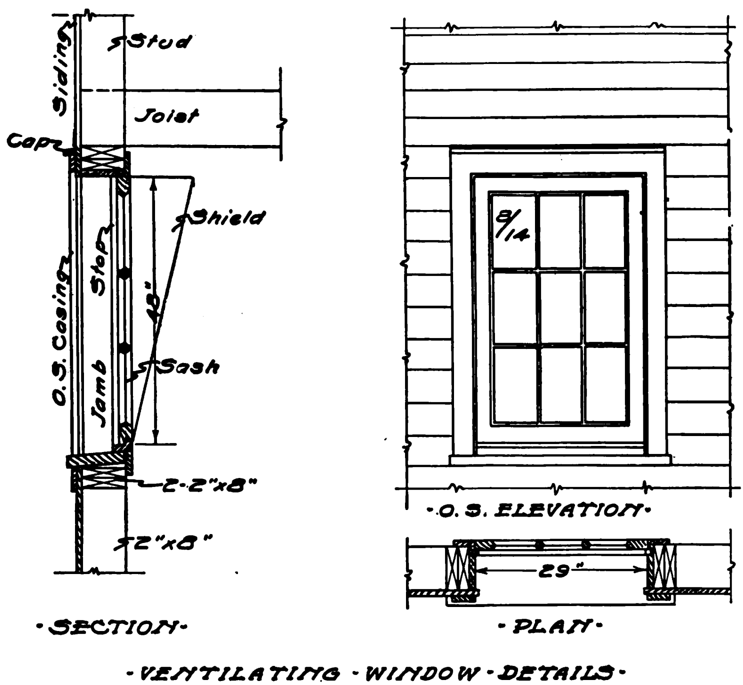
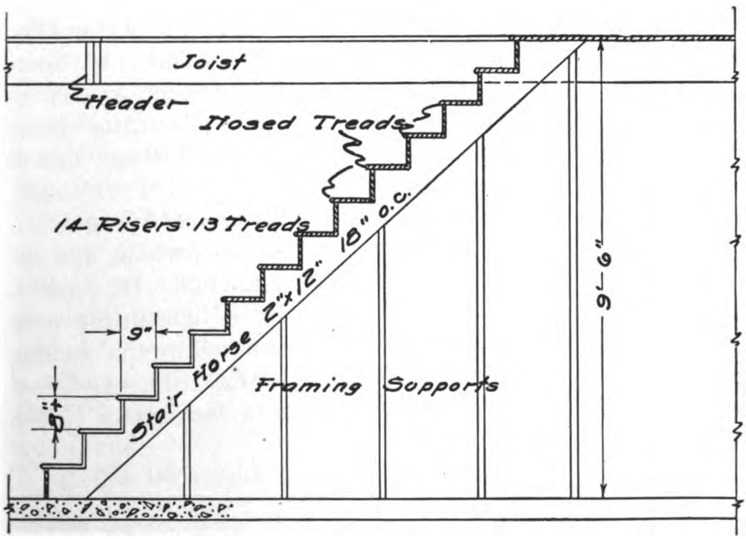


FIG. 52.—Details of a barn window.

since there is a smaller proportion of light cut off by the walls.

The windows should be framed into the wall at the under side of the joists. Metal shields are sometimes provided to deflect the air upward, and prevent drafts directly on the stock. Ventilating windows should not be depended on to provide all of the necessary fresh air in winter.



·DETAIL OF BARN STAIRS·

FIG. 53.

The best appearance is secured in dormer windows by making them wide and low.

Stairs.—In many plans there is no provision made for a stairway and the only way to the loft is by way of a ladder. A stairway takes up but very little room, and is safer and more convenient than a ladder. The width of the stairs is 2½ to 3 feet, and a rise of 8 inches and a tread of 9 inches are desirable. There should be not less than 7 feet of headroom at any part of the stair. Care should be taken that no vital part of the

frame is weakened by the opening. A hood or framework built over the stair opening into the loft will prevent it from being closed over when the loft is being filled.

Hay Chutes.—Hay chutes should open directly into the feed alley, or into a cross alley connecting with the feedway. If the chutes come in the center of the barn, the framework around the opening is carried to within about 14 feet of the roof, in order that a sling load of hay will pass over it. Boards placed over the top of the chute prevents it from being filled with hay from the slings. The framework may be open, simply to keep a clear opening to the stable, or it may be covered tight, and doors provided at intervals. The chutes are sometimes carried to the stable floor, and closed off, to keep dust and chaff out of the stable.

Sometimes the hay chute is used for a ventilating shaft, but this is not recommended, as the location is wrong, and the foul air flue should have no openings in the loft. It is well to close the hay chute from the stable by a tight-fitting door when not in use, as the ventilation is disturbed by the opening in the ceiling. The proper size for the hay chute is 3 feet square. One chute should be provided for each ten or twelve head of stock.

CHAPTER VIII

CLASSIFICATION OF BARNS

BARNS differ with respect to use, shape, height, style of roof, and the material used in the construction. For a full understanding of the subject, it is necessary to classify barns according to their various characteristics, and study the important points of each classification.

Use of Barn.—The use to which a barn is put refers to the special purpose for which it was built. According to use, then, barns are classed as dairy, horse, beef cattle, sheep, and general-purpose barns. These different uses have been discussed fully in the preceding chapters.

Shape.—In shape the barn may be classed under one of the following heads: square, rectangular, L-, T-, or U-shaped, and round.

It has been said that the barn planned to accommodate two rows of stock placed lengthwise was the best. The square barn is economical, and if this shape permits of a good floor plan there is no objection to the square form. For barns longer than 34 or 36 feet there is no advantage in increasing the width to correspond to the length, as the loss in convenience and economy of arrangement offsets any economy of construction.

The rectangular barn of sufficient width to accommodate two rows of stock is the most common shape, and is usually to be preferred to any other shape. The length can then be made to suit any condition, or existing barns may be extended, if the herds are much increased. There is no limit to the length of the rectangular barn. The authors have designed barns 150 feet long which have given good service.

Lighting, ventilation, and floor-plan arrangement can be worked out to best advantage in the 34- or 36-foot barn. Most standard plans for framing are for barns of these common widths, and the members of the frame are designed to carry the loads that come on about a 36-foot span. The practical limit of the self-supporting roof of plank construction is 42 feet. The 34- to 42-foot barn permits of economical handling of hay in the loft, as the entire mow can be filled from one line of track, and practically without hand pitching.

The L-shaped barn is desirable for conditions found on many general farms. The barn is usually placed to form a sheltered yard in the angle of the two parts. The main part should serve for the principal stock, the ell being used as a feeding barn, cattle shed, or as storage space. To avoid interference with light and ventilation, the main barn should be placed with the long axis north and south, and the wing attached at the north end, on either side.

The T-shaped barn is the common arrangement for a two-story feed and hay barn, and a one-story stable. One section may be built to meet the requirements for a time, and the other added as the herds are increased. The one-story stable is low in cost, and except for hay storage, is quite efficient.

The U-shaped barn is usually associated with extensive stock-raising interests, and as commonly built, consists of two separate barn units, parallel to each other, and connected by a feed storage, passage, or shelter wall. The sheltered yard so formed is valuable. For the average farm this type is not practicable.

Round Barns.—Although the use of the round barn is not general, almost every man who plans to build has the round barn plan brought to him for consideration. Because of the several important points both in favor of and against this style of barn, the advantages and disadvantages will be covered quite fully.

The round barn incloses the most area with a given length of wall, for the same reason that a circle encloses the most

area; since there is less exposure than in the other shapes; the barn is warmer; round construction is the strongest type; there are no corners for the carpenter or mason to construct, so there is time saved in the construction. The usual plan includes a silo in the center of the barn, which makes feeding convenient when the stock faces the center. Silage will not freeze, because it is protected by two walls. Hay capacity is increased in the round barn as compared with the rectangular.

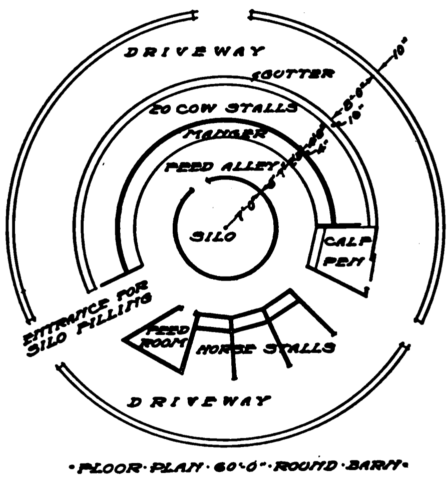


FIG. 54.—Floor plan of a round barn.

There are, however, certain disadvantages in the use of the round barn, considered in connection with the other types. To offset the saving in wall, the round barn wastes some space; since the stock is placed in a row, around a circle, there is waste space behind the stock, if they are afforded sufficient room in front. Less wall space means less light, and furthermore, the direct light is not effective over a wide space of wall at any one time. Light must reach 30 feet from any one window to the center of a 60-foot barn, compared to 18 feet in the 36-foot rectangular barn. Ventilation is harder to handle in the round barn, since the foul air flues should be carried up from the side walls, and empty into one ventilator at the center.

Builders in most places are not familiar with round barns, with the result that time and material are often wasted.

The silo in the center of the round barn is inconvenient to fill. Spoiled silage when thrown out causes objectionable odors in the building. The result of placing the silo in the

center of the barn is to surround it with two walls, instead of only one, and the protection afforded costs more than it is worth.

A large round barn is more economical than barns of small diameter. But the larger the barn, the more difficult becomes the lighting, ventilation, and satisfactory arrangement.

Height of Barns.—Barns are referred to as one-story barns, story and a half, and two, or even three stories high. In some sections also, the basement barn is common.

The one-story barn is simply a stable, without feed storage above, and may be used as a wing in connection with a storage barn, or as a separate building. The one-story barn is usually the lowest in cost of any of the heights, but not

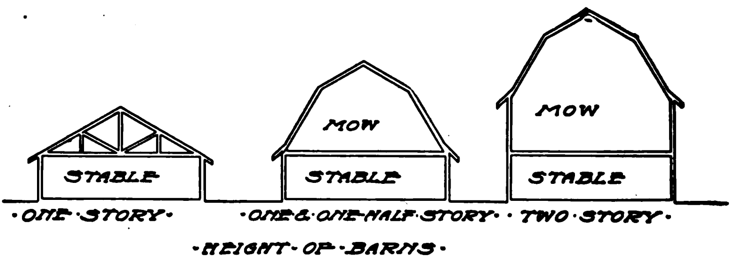


Fig. 55.—Relative heights of barns.

necessarily the most economical, as the same roof and foundation might be utilized in building additional hay space. The one-story barn is usually of the gable-roof or shed-roof type.

The story and a half barn provides a certain amount of hay space, the side walls above the stable being not more than 6 feet high. If a gambrel roof is used, the lower rafters may come just over the loft-floor joists. This type of barn is used if only a limited amount of hay storage is wanted.

The two-story barn is the most economical and the most common on the general farm. The walls are from 8 to 18 feet above the first story. The self-supporting plank frame roof is recommended for best results in hay storage.

Three-story barns are not common, and for average con-

ditions have very little to recommend them. If stock is kept on the second floor, it is necessary to make the floor of plank or reinforced concrete, waterproofed. The services of an engineer are needed to figure the reinforcing, and the problem of waterproofing is somewhat difficult and expensive.

The basement barn has the first-story walls built of masonry, and all or a part of the stable walls are below the level of the ground; it has the advantage of protection from the wind and cold, and it is also easy to drive into the second story. The basement barn, however, is hard to light and ven-

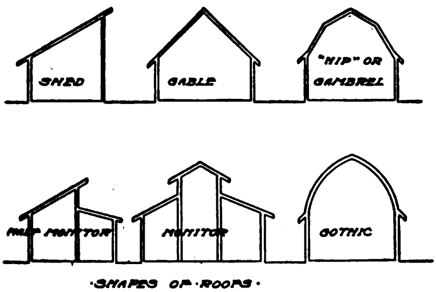


FIG. 56.—Types of roof shapes.

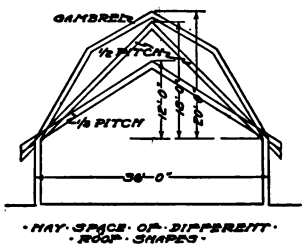


FIG. 57.—Illustrating hay storage space in under roofs of different shapes.

tilate, and the walls are likely to be damp. The best results are secured with this type if at least 4 feet of the lower wall is above the grade line.

Roof Shape.—There are some common roof shapes that are not understood by the average student or builder, and a few types are incorrectly named. The object of this discussion is to point out the common roof shapes, and the relative merits of each.

The shed roof is a single-slope roof, simply constructed; it is used principally for cheap buildings, or for a "lean-to" in connection with another building. The pitch is low, usually not over one-third pitch being used.

The gable roof is the common two-slope roof, widely used

on houses, hog houses, garages and the like; it may be made attractive, and is best for many uses. Few modern barns have the gable roof, as wide buildings require purlins and braces in the loft, and the hay storage is less than in the newer roof types. The common pitches range from $\frac{1}{4}$ to $\frac{1}{2}$.

The gambrel roof which has two slopes on each side is undoubtedly the most practical for the farm barn. The lower set of rafters is set at about 60° with the horizontal and the upper slope is about 30°. The gambrel roof is easily made self-supporting, affording an unobstructed loft. The most difficult problem in connection with the gambrel roof is to secure good proportions. The method to be followed is fully outlined in Chapter X.

The Gothic, vaulted, or arched roof is increasing in popularity for use on farm barns, as having no obstructions in the loft, and the entire strength is secured by the arch construction. The cost is higher than for the other types, as the labor and material necessary to secure the smooth curve make it more expensive. The shape of the roof may vary from nearly flat up to a height equal to about $\frac{2}{3}$ the width of the barn. The higher shapes afford the most hay storage and are easier to construct.

The monitor barn roof results from the higher roof on the center or main part of the barn, and sheds on either side. It is used in dairy barns in the warmer climates as the upper portion collects the warm air, and aids in cooling the barn. For this reason the monitor barn is not recommended for dairy cows in the colder sections. For beef cattle barns, the monitor barn is satisfactory, if the main portion is used for hay storage, and the sheds for the stock.

Materials of Construction.—Locally, at least, barns are often referred to by the material from which they are constructed. The materials in common use are wood, stone, cement blocks, monolithic concrete, and hollow tile, and the available materials should to some extent determine the kind to use. Often a combination of two or three materials can be made to good advantage. In selecting the material the com-

parative advantages of appearance, sanitation, permanence, economy, and first cost should be considered. The kind of materials used in other buildings in the groups should also be considered.

Standard Barns.—Some attempts have been made to standardize barn plans, for various purposes. Some popular house and barn plans have been used many times, and with success. If it were possible to have a standard for each type of barn the farmer would need and so arranged that he could find a barn that met his exact requirements, his barn plan problem would be solved. Some of the obstacles to standard plans are given here. The type of farming is the first consideration, for the barn would first of all need to be suited to the purpose. The locality would have some effect, for different conditions prevail in Georgia and the Dakotas. The number of stock kept on the farm varies an unlimited number of times. To meet all requirements, there would need to be standards for each type of framing, each floor plan, each height, and each material used in the construction. If all of these points were provided for, there would be a confusing number of standards, and the value would be lost.

The authors believe that some parts of the plan and construction could be standardized. The ceiling height, manger, stall width, size of gutter, and many parts of the plank frame have been developed by long usage into more or less ideal form. By accepting these items as best, the farmer or builder would be saved the annoyance of experimenting. For the plan, and the building itself, almost every barn is a special problem, and will have to be solved as such.

CHAPTER IX

BARN CONSTRUCTION

THE correct framing and construction of the barn has a direct effect on the economy of the building, for it is possible to save by good care, or to waste by the improper use of material. Details are important, for upon them depends the value of the completed structure. The following discussion is not intended for the builder who is already familiar with most parts of construction, but rather for the student and farmer, who should know the features of good construction. The discussion in the following two chapters embodies the practices generally adopted by those connected with any phase of building or designing.

Factors Affecting Construction.—Climate has a considerable effect on construction, for the Southern barn does not need to be designed to keep out the cold, but it must have a good roof. In the North, the foundation must extend below the frost line, and the walls be made tight. If there is a probability of high winds, the barn must be strong and well braced. Farming methods determine whether the barn is to be a strong, permanent, well-built structure, or a cheap shelter. Kind of stock determines whether the barn is to be an efficient farm factory, or just a shelter from the elements. Barns with hay capacity must have stronger supports and heavier framing than the one-story shed. Legal restrictions may determine to some extent the kind of barn to be built.

Definitions.—To understand fully the construction of barns it is necessary that the reader be familiar with the terms used. The following terms are those most used in considering construction work, and the common usage is given:

Footing.—The broadened base of the foundation or pier, which supports the foundation wall or column.

Foundation.—That part of the building which supports the wall of the superstructure, usually of masonry, and extending from the footing to the ground level or above.

Pier.—The masonry support for column or sill, usually square or rectangular in shape.

Sill.—A horizontal member resting on foundation or pier and forming the bottom of the wall.

Column.—Upright member supporting floor girders or purlins.

Girder.—The beam which rests on the columns and supports the floor joists.

Joist.—The beam or support which holds the floor, and to which the flooring is fastened.

Studding.—Vertical wall members, extending from sill to plate, forming the skeleton of the wall, and to which sheathing, siding, and lath and plaster are fastened.

Plate.—The horizontal member at the top of the studding.

Ribbon.—A horizontal piece notched into the studding, to help support the floor joists at the wall.

Rafter.—The framing member of the roof, which holds the roof sheathing.

Lookout.—The projecting end of the rafter, or short pieces to frame the eaves, or the "overhang" of the roof.

Purlin.—A horizontal member intermediate between the plate and ridge, supporting the rafters.

Sheathing.—The covering or boxing over the framework of the building.

Truss.—A built-up structure, composed of several pieces, acting together as a beam to support a roof or floor span.

Bent.—The interval between trusses, measured from center to center of truss.

Collar Beam.—Cross braces on pairs of rafters, near the ridge.

Self-supporting Roof.—That type of roof construction without supporting members within the loft.

Timber Frame.—Roof framing consisting of pieces larger than 2 inches thick, for the principal members.

Plank Frame.—Construction in which none of the material used is larger than 2 inches thick.

Preliminary Work.—The exact size and shape of the barn must be determined before the construction work can be started. The ground should be brought to the desired grade by cutting and filling. The foundation should not be placed on filled or made ground until it is thoroughly settled. Corners may be squared by making a triangular frame with sides 3, 4, and 5 feet long. The larger angle will be 90°, or a right angle. To check the rectangle of the building, the diagonals should be measured, and made equal.

Before the foundation is made all tile lines and drains should be located and constructed, and their exact location marked on the plan or on a map. Openings for doors should be marked off exactly, in order that the masonry foundation may be built to leave the door openings above the ground level.

The trench for the foundation, if carefully dug, and widened at the bottom, will serve as the forms for concrete. Above the ground, wood forms, well braced, are used. Forms should be carefully leveled, to give a foundation that is straight and true.

Foundation.—The foundation should be extended below the frost line, and down to firm soil. This depth will vary, but for average conditions should be 3 to 4 feet below the grade line. The foundation wall should be not less than 10 inches thick if of concrete. Stone walls are made about 2 feet thick. The base or footing should be between 12 and 20 inches wide,

to prevent settlement. The foundation of masonry should be carried at least 1 foot above the ground to keep the framing away from the damp ground. In many barns the foundation is carried to a height of 4 feet above the ground. This affords a permanent lower wall for the stable, and is more easily kept clean than frame construction.

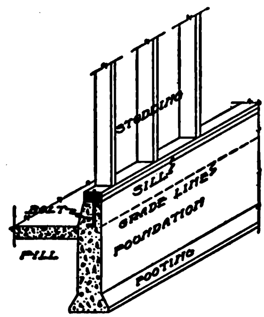


FIG. 58.—Good type of foundation wall and sill.

A wet mixture of 1: 2: 4 concrete is best for foundation work. Above the ground the forms should be tight and smooth. Bolts, $\frac{5}{8}$ by 18 inches, should be placed in the wet concrete at intervals of about 6 feet. The sill is then bolted to the foundation. The foundation should be made separate from the floor, in order to avoid cracks in the latter, in case the foundation wall settles slightly.

Hollow tile, brick and stone are used to some extent for foundations. These materials are laid up in a manner similar to that used in ordinary wall construction. The barn foundation should be continuous, rather than in the form of piers. The appearance is better, the building is warmer, and there is less danger of rodents burrowing under the building.

Floors.—Barn floors are made $4\frac{1}{2}$ or 5 inches thick, of two-course concrete, for best results. The construction of floors is discussed elsewhere in the text. The floor construction is usually delayed until the framework of the building is completed. Anchors and bolts are placed when the concrete is poured. Floors should be given sufficient slope to carry all water to the drains.

If the ground about the building is well drained, the floor may be laid directly on the ground without filling. A fill of about 6 inches of cinders, gravel, or crushed stone forms a good base for the floor, and should be used if the barn is located on low, wet ground.

If cork brick or creosoted wood blocks are to be used in

the stalls, the top course of concrete is not put on, and a depression is left in the floor sufficient to receive the blocks. A retaining curb 6 inches wide is placed at the rear of the stall next to the gutter.

Masonry Walls.—The types of permanent materials used in barn walls are concrete, hollow tile, brick, stone and concrete blocks. They afford a fire-resisting wall which is easily cleaned and does nor require painting.

Concrete walls are made 10 to 12 inches thick. Tight forms are required, and care is necessary to get a smooth, even wall. Openings for doors, ventilating flues, and windows must be formed in the concrete as it is made. Reinforcing is

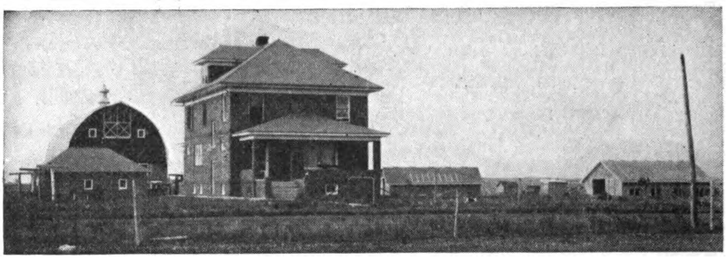


Fig. 59.—Permanent construction in farm buildings.

necessary if the concrete extends above the openings. Two-inch plank frames around the openings are necessary.

Hollow tile is an excellent material for barn walls. The wall is made 8 inches thick in most cases, although 12 inches is used in some barns. The usual block is 5 by 8 by 12 inches, with two or three air cells. The mortar joints average $\frac{5}{8}$ inch thick. Portland cement mortar, either white or colored, may be used, a red or brown mortar usually resulting in a better appearance than the white. If openings are spaced according to the length of the blocks, the trouble of cutting fractional blocks will be avoided. Brick is sometimes used to fill in the corners, although half-blocks may be secured.

Cement blocks are laid up in much the same manner as the hollow tile, and form an 8- to 12-inch wall. The blocks are

more easily handled than the monolithic concrete, and the cost is less; they may be purchased in a variety of forms, or may be made on the farm, if the necessary materials are at hand.

Brick and stone are used only to a limited extent, and will not be considered except briefly. The average brick is $2\frac{1}{2}$ by 4 by 8 inches in size, and requires a mortar joint $\frac{1}{4}$ to $\frac{3}{8}$ inch thick. The wall should be at least 9 inches thick. Stone walls are 20 to 24 inches thick, laid up with cement mortar. If a supply of stones is at hand, they may make an economical barn wall, but the cost is excessive if much labor is involved in getting them.

Barns built entirely of concrete or other masonry material have been built, but they are not yet practicable for the average farm. The cost is high for the masonry roof, and few builders doing farm work are equipped for handling the work. If the walls are made entirely of masonry, and the roof of frame construction, the problem is simplified somewhat. With masonry walls to the eaves, however, it is rather difficult to frame properly the self-supporting roof. It is doubtful if there is any advantage in building the walls of masonry above the first story. Practically all of the advantages of the masonry walls are secured below the second floor.

The authors believe that the best results can be secured if the first story is made of permanent materials, and the upper part of frame construction. If it is desired to fireproof the barn on account of the value of the stock, it is suggested that the stable be made fireproof by masonry walls, steel fixtures, and a reinforced loft floor. It is cheaper to risk the danger of fire in the loft than to attempt to fireproof the whole building.

Sills.—If the foundation is made continuous, the sill usually consists of two pieces of 2-inch lumber, 6, 8, or 10 inches wide, according to the thickness of the wall. The sill should be laid in a bed of mortar, on the foundation, and made level. If bolts have been placed in the foundation, the sill may be bolted fast. The double thickness sill can be spliced by breaking joints, and the strength is not harmed. In

barns built on piers, as in the case of many old structures, the sill was of the heavy timber type, perhaps 10 inches square.

Plates.—The wall plate is of the same material and construction as the sill; it is fastened to the studding and serves as a seat for the rafters.

Studding.—The vertical wall members vary from 2 by 4-inch material in the small barn, to 2 by 10 inch in the lower walls of the well-built barn; 2 by 6 and 2 by 8 inch are the most common sizes. The usual spacing in barns is 2 feet

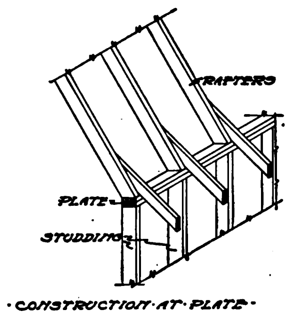


Fig. 60.—Detail of typical plate and cornice.

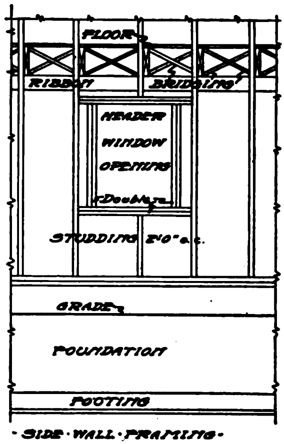


Fig. 61.—Typical method of framing about a window.

apart on centers. Studs are doubled at each side of openings, and are double or triple at the corners.

Columns.—The columns or posts may be of solid timber, built-up lumber, or of iron or steel. The common sizes are 6 by 6 wood, or 4 and $4\frac{1}{2}$-inch iron or steel, for average conditions. The length of the column and the load to be supported should be considered, for best economy. Posts should always be spaced to fit the floor plan, and the plan should be fully decided upon before the posts are located. In "face-out" plans the posts should come at the rear of the stall partitions, and in the "face-in" plan the posts are placed

just behind the stall frame. Steel posts, concrete filled, are preferred to any other type.

Girders.—The load on the girder should be ascertained, and the size determined accordingly. The built-up girder, made from several thicknesses of 2-inch lumber, is preferred. The joints can be distributed so the girder is not weakened at any one point; the continuous beam is somewhat stronger than the simple beam that is broken at each support. The girder should be supported by a post at intervals not greater than 14 feet. A comparatively deep, narrow girder is stronger for the material used, than a square or shallow one. A common size is built from five pieces of 2 by 10-inch lumber, however, the size should be figured in each case, if possible.

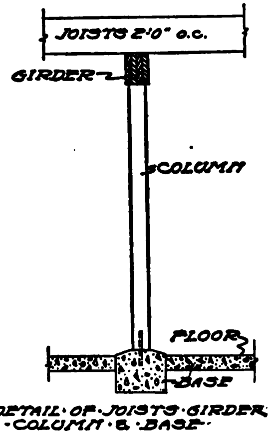


FIG. 62.—Detail of column, joists and girder.

Joists.—The floor joists are 2 inches thick, and vary according to the load, from 8 to 12 inches deep. The joists should run crosswise of the barn, and be lapped above the girder. The total length of the joists across the barn should exceed the barn width by about 2 feet, to allow for lapping. The usual spacing is 2 feet apart on centers, although a 16-inch spacing is sometimes used. Joists should be bridged once in 8 feet, and twice in a 14-foot span.

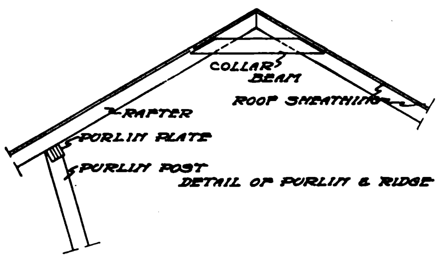


FIG. 63.—Details of typical ridge and purlin.

Rafters.—Barn rafters are almost without exception made of 2 by 6-inch material, and spaced 2 feet on centers.

Long rafter lengths are sometimes supported between the plate and ridge with a purlin. In the self-supporting roof the rafters are usually braced in pairs, to form trusses.

Bracing.—The principal bracing in the barn frame will be considered under the subject of roof framing. Aside from the main frame, additional braces are required for rigidity. Diagonal braces and end braces in the barn are necessary to withstand the action of the wind, the location depending on the plan.

Sheathing.—Wall sheathing is often omitted in barns, and the siding nailed directly on the studding. In cold sections, or where an exceptionally good barn is desired, the

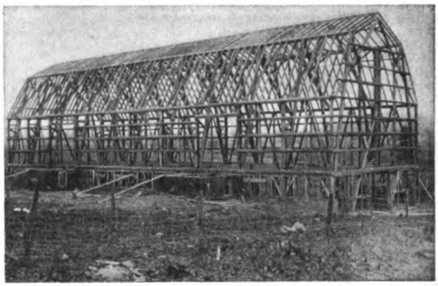


FIG. 64.—A barn frame of the Shawver type.

sheathing is used. The usual wall sheathing is either shiplap, or inch boards, No. 2 grade being generally used. Some builders put the sheathing diagonally on the studding, for the bracing effect, though usually it is placed horizontally.

Roof sheathing for prepared roofing or slate or asphalt shingles is put on solid. For wood shingles, the sheathing consists of 1 by 4-inch boards laid with a 2-inch space between them.

Siding.—Siding is available in a number of forms, the most common for barns being bevel siding, drop siding, matched boards, and plain boards with battens. Either horizontal or vertical siding may be used, and the kind depends principally on the type of framing. The plank truss frame usually

takes vertical siding, and the braced rafter frame the horizontal siding. Weather-resisting woods such as white pine, cypress, cedar, and redwood are preferable for siding.

Ceiling.—Ceiling lumber is matched, dressed, and beaded, and is used in place of sheathing on the projecting ends of the rafters, if the open cornice is used. Good dairy farms are ceiled inside both on the ceiling and side walls. Clear pine or fir is the common material used, the $\frac{5}{8}$-inch thickness being most widely used.

Loft Floors.—Loft floors should be made of dressed and matched lumber, the most suitable material being pine or fir, 1 by 6-inch flooring. The floor should be made tight, to prevent dirt and chaff from sifting through into the stable. Double floors are not common, although in some barns they are used because of the greater cleanliness secured in the stable.

CHAPTER X

BARN FRAMING

THE framing of the barn, and especially of the barn roof, is one of the most important problems in the design and construction of barns. The objects are to secure a strong, rigid frame, with the least amount of lumber consistent with strength, to avoid obstructing the hay loft with large timbers, and to reduce the amount of labor necessary to erect the frame. The method which seems most nearly to meet the requirements is the plank frame. The method formerly used is known as the timber frame.

Timber Frame.—The timber frame consists of sills, posts, girders, and braces of large timbers, ranging up to 12 by 12-inch pieces, the heavy pieces being usually mortised together. For the most part the timber frame is no longer being built, except in certain localities where lumber is easily secured and local mills furnish the greater part of the supply.

The advantages of the timber frame are that it is strong and substantial, and many carpenters who are not familiar with the plank barn will build the timber frame.

The disadvantages are that about 20 per cent more lumber is used than is necessary for strength, and the labor of erecting is greater than for the plank frame; in most parts of the country the larger sizes of lumber are not available except on special orders; the cost of large sizes is more than for 2-inch lumber; the braces and cross beams in the loft interfere with the use of hay unloading machinery. The illustration is given for comparison with the lighter frame, and is not recommended.

Plank Frame.—The plank-frame barn is built without the use of any material larger than 2 by 12 inches. All pieces are

readily secured in practically every lumber yard. The greatest length necessary is about 24 feet for a few braces or supports, and these pieces may be spliced from shorter lengths. Girders or posts requiring more strength than is given by one piece are built up from two or more 2-inch pieces. The use of 2-inch members in the trusses of the braced rafter and plank truss

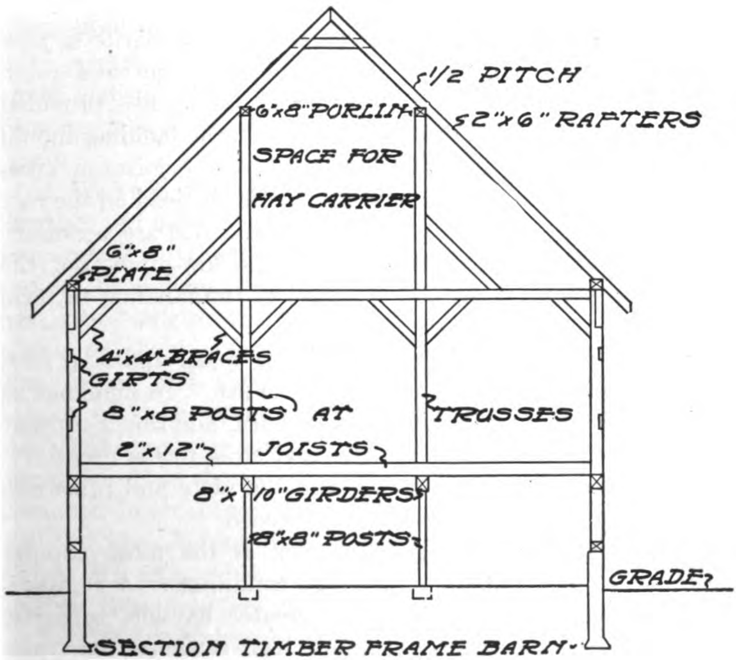


FIG. 65.—Illustrating timber framing for barns.

frames has made the self-supporting roof common on farm barns. Less lumber is needed in the plank frame, and sufficient strength is secured by the proper placing of the material. Less labor is required in the construction of the plank frame as compared with the timber.

The sizes of material used in the plank frame are figured for spans of from 32 to 40 feet. The trusses discussed here

should not be used on very wide barns without additional material being used. The sizes of material used in the plank frame have been evolved from many years of construction work. Some figures have been announced which show that the practical sizes tally closely with the theoretical requirements. The reader will be able to determine the correct sizes of joists, girders, and supporting posts by referring to the discussion in Chapter XXX.

Gable Roof Framing.—The gable roof for barns is now commonly used on the one-story building. The roof pitch varies from $\frac{1}{4}$ to $\frac{1}{2}$. If there is no storage space provided overhead, the lower pitch is satisfactory. The building should be tied together at the plate either by ceiling joists or cross ties, to prevent spreading. A large part of the load on the roof tends to thrust outward at the plate, and ties are necessary to prevent sagging and bulging. In the low-pitch roof the rafters are extended beyond the edge of the building to form the lookouts.

Rafters are 2 by 4 inches in size for spans under 20 feet, and 2 by 6 for all spans greater than 20 feet. In buildings as wide as the average machine shed or barn, additional support above that afforded by the rafters and cross ties is necessary. A purlin plate, intermediate between the plate and ridge and supported by posts from the floor, is needed.

Gambrel Roof.—The gambrel roof is the most popular type and is practical for all average conditions. A comparison with the gable roof shows a greater hay-loft capacity. The gambrel roof barn has more hay capacity than any other type except the Gothic, which is not in common use.

The gambrel roof is sometimes erroneously termed " curb " roof or " hip " roof. The hip roof refers to a very different type of roof, and neither term is correct.

Layout of Roof.—Poor proportions result in a poor appearance, and weakened construction, in the case of the gambrel roof. The common faults found in existing barns are that the two pitches are made nearly equal; the upper part is made too flat; the lower pair of rafters are too long; or the angles

of both sets of rafters are not correct. The three suggestions which follow, if taken together, should result in a well-proportioned, strong frame:

1. Since the arch is one of the strongest forms of construction, the truss of the gambrel roof should act in a way similar to the arch. To secure a truss following the lines of an arch, construct a semicircle, with a radius equal to one-half the width of the building. Place the center on a level with the plates and midway between. The break in the roof will come near the arc of the circle, and the ridge will be somewhat above the circle.

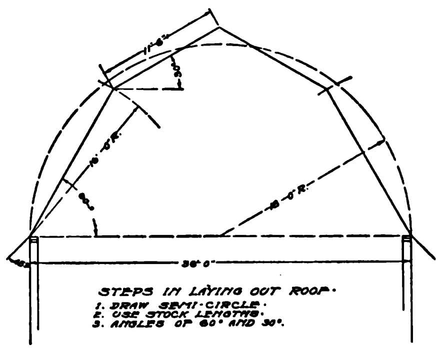


Fig. 66.—Illustrating method of laying out gambrel roof.

2. The use of stock lengths of lumber is economical, and the roof should be designed to use stock-length materials or slightly less. The upper and lower rafters may be about the same length, or the upper pair 2 feet shorter than the lower ones. Lengths of 16 and 12 feet work out well for the 36-foot barn. Other combinations for various widths are 14 and 14 feet; 14 and 12 feet; and 12 and 12 feet; or 12 and 10 feet on narrow buildings.

3. The lower slope of the gambrel roof should be approximately 60° with the horizontal, and the upper slope about 30°. There may be slight variations from these angles, of 5 to 8°. In the 36-foot barn the break in the roof is about 7 feet from the plate, measured along the "run" of the rafter.

Types of Gambrel Roof Framing.—The two methods of framing the gambrel roof in the plank frame construction are known as the "braced rafter" and the "plank truss" construction, the latter being also known as the Shawver

frame. The use of these two types of plank framing seems to be about equally divided. Both types have been used for a number of years, and have proven amply strong. Personal preference will largely determine which of the two methods will be chosen. The floor plan and arrangement of the barn does not affect the type of framing. Either of the two styles of framing discussed here may be used with any plan.

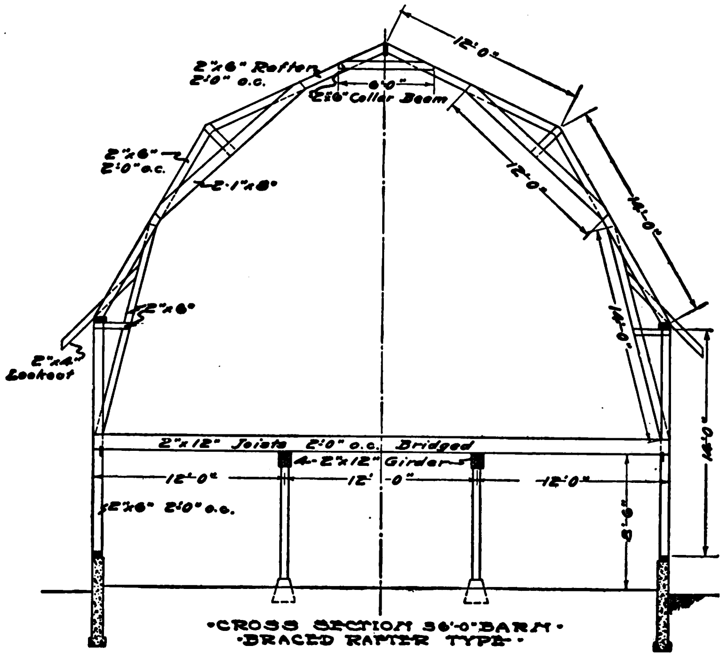


FIG. 67.—Typical braced rafter construction.

Braced Rafter Frame.—In this type of framing the studding are spaced 2 feet apart on centers. The floor joists are set crosswise of the barn, with the same spacing as the studs. Each joist is nailed securely to the studding, and a ribbon is notched into the studding just below the joists. Horizontal siding should be used, as the siding can then be nailed directly to the studding without the use of nailing girts. The studding

extend from the foundation to the plate without a break. The wall framing to the plate is completed before the roof is framed.

The distinguishing feature of the braced rafter frame is the fact that each set of four rafters is braced at all angles, to form a light truss, which supports the roof through a length of 2 feet, which is the spacing of the rafters, no purlins or extra framing being necessary. Each truss consists of two lower rafters, two upper rafters, a collar beam, or tie, and upper and lower braces. The upper braces are made approximately the same length as the upper rafters, and extend from the center of the upper rafter to a point about 7 feet below the angle of the roof on the lower rafter. The lower brace is about the same length as the lower rafter, and extends from just above the second floor to the point where the upper brace attaches.

In erecting the roof frame the pieces are all cut on the ground or loft floor, and nailed together, with the exception of the lower braces. The builder should determine the length of the pieces and the angle of cut, and cut all rafters and braces first. The rafters are then laid out on a smooth surface, and the collar beam and upper braces nailed fast. The trusses are then piled on the loft floor if the side walls are low, or on a temporary platform if the side walls are high. The foot of each truss is then placed on the plate, and the truss raised with a gin pole and block and tackle. When raised, the truss should be braced with temporary supports, and nailed at the plate. The lower braces, connecting the truss with the studding, are then put in place. After four or five trusses are raised, they can be trued up, and sheathing boards nailed on to hold them in place. The lookouts can be put on after the trusses are all raised. Lookouts may be made from 2 by 4-inch lumber if desired. They are usually set at an angle of 45°, and project over the building line a distance of 18 inches to 2 feet. Short braces may be added to the truss, as shown in the drawings.

The entire framework of the roof in the braced rafter barn should be made from 2 by 6-inch lumber. The braces are sometimes made of 2 pieces of 1 by 6 or 1 by 8-inch material,

but this requires extra cutting, and the same amount of lumber. The studding for most barns of this type should be 2 by 6, or 2 by 8.

At the ends of the barn the plate is carried across at the square, or even with the sidewall plate. The studding are spaced at 2-foot distances, from foundation to plate. Short studding are used to fill in the gable end. The hay door will

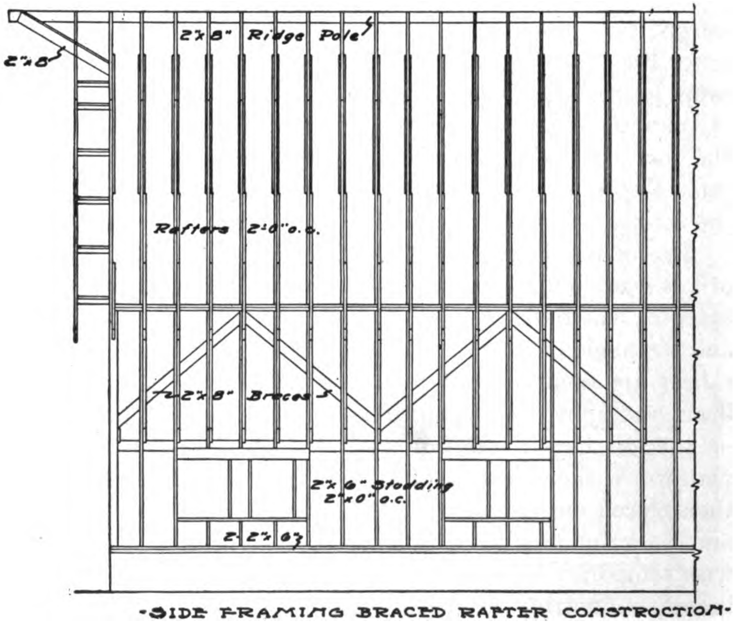


FIG. 68.—Side elevation of braced rafter construction.

be framed in at one end of the barn. Wind braces, or end braces, perpendicular to the end of the barn are necessary to prevent the barn from swaying. Diagonal braces throughout the barn are desirable to strengthen the building.

The advantages of the braced rafter frame over the plank truss frame are: Lighter material is needed; fewer men are needed to handle the job; the loft is practically free from any obstruction; and about 10 per cent less lumber is required.

Plank Truss Frame.—The trusses in this type of framing are placed 10 to 16 feet apart, with 12 and 14 feet as the usual spacing. These trusses support the entire roof load, and are naturally heavier than the truss of the braced rafter frame. The space between the trusses is filled in with braces and rafters. The most widely used method of construction calls for the building of the entire first story before the trusses are made and erected. The studding are short, and extend only to a plate under the floor joists. The columns and girders

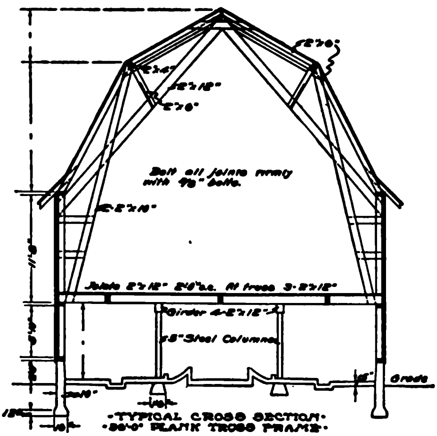


FIG. 69.—Typical Shawver barn frame.

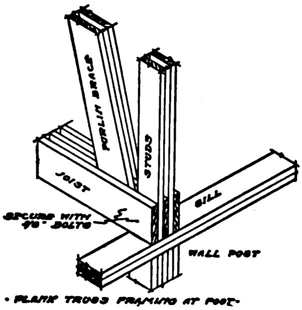


FIG. 70.—Details of construction at foot of truss, Shawver frame.

are set, and the joists then placed much as they would be on an ordinary house or barn foundation. The second-floor joists are then practically covered with the flooring boards, to form a large platform on which to work.

In the first story of the plank truss barn, the wall studding are not spaced at regular intervals, but according to the openings. Diagonal braces are placed at frequent intervals between the openings to strengthen the frame. The plate under the joists serves as the header for the top of the openings in the first floor. At the truss intervals, or 12 to 14 feet,

several pieces of studding are set together to form a post on which the truss is supported. It will be noted that no window or other opening can come under a truss because of this post.

Each truss is made up of the following parts: A cross tie extends across the building at the truss, which consists of three pieces, the same size as the joists. The pieces are set with short blocks between them, for splicing, which gives a three-ply piece, with two 2-inch spaces. Purlin supports extend from the joist line to the purlin. They are made up of two pieces of 2 by 10 or 2 by 12-inch material, with a 2-inch space between the pieces. Roof or purlin supports extend from just below the plate to the ridge of the roof. The wall post consists of two pieces of 2 by 8, with a 2-inch space between. A 2 by 4 brace extends from the purlin to the ridge. These pieces, together with the short braces, as shown in the illustration, form the truss. The truss is built on the loft floor, and later raised into position. The upper roof braces fit into the interval between the two pieces of the purlin support. The two pieces of the purlin support and the wall post fit into the intervals between the pieces in the cross tie, and when erected, form a rigid structure.

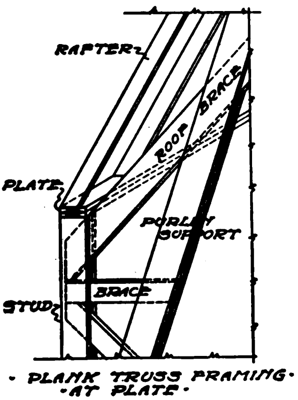


Fig. 71.—Details of construction at plate, Shawver frame.

The principal parts of the truss are bolted together at each joint. The trusses are raised by means of the gin pole and pulleys. A team of horses aids in raising the truss, and guy ropes should be used to steady it. The illustrations show how the trusses are erected and braced. The intermediate rafters, braces, and nailing girts may be put on as soon as two or more trusses are in place. The purlin may be built in sections on the ground and raised, or it may be built in place.

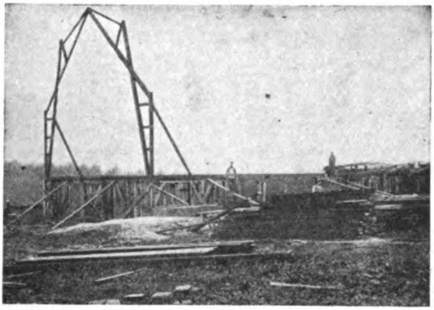


FIG. 72.—Erecting first truss, Shawver type of construction.

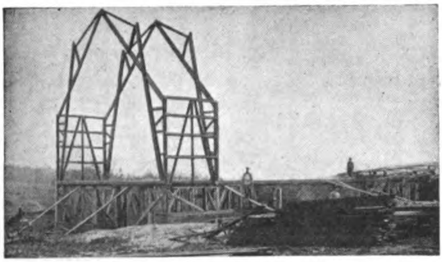


FIG. 73.—Erecting second truss, Shawver type of construction.

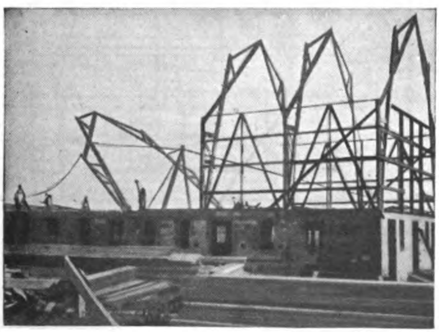


FIG. 74.—Shawver frame being completed.

There is another method of constructing the plank-truss barn which is used to some extent. Instead of building the first

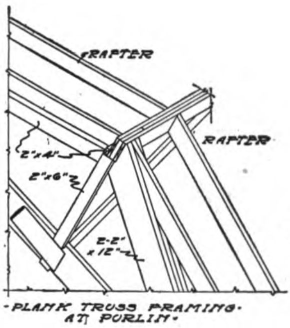


FIG. 75.—Details at purlin, Shawver type of frame.

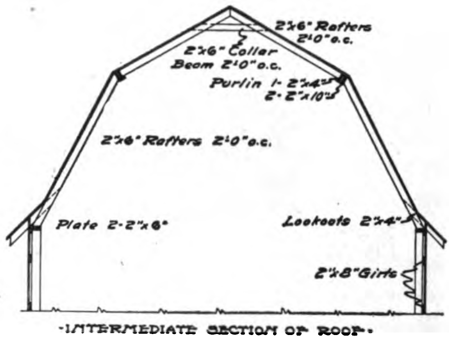


FIG. 76.—Section between trusses, Shawver type of construction.

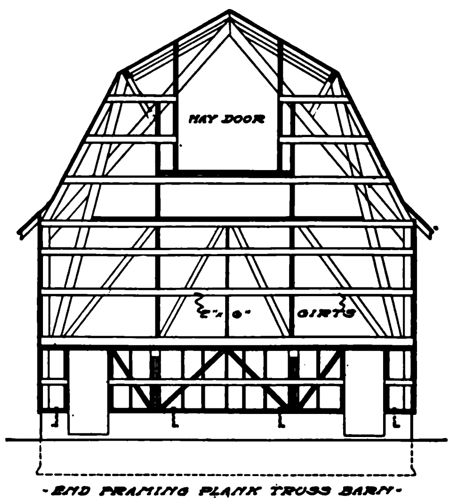


FIG. 77.—End framing Shawver type of construction.

story before the trusses are raised, the latter are made to extend from the foundation, and there is no break at the second

floor. The advantage of this method is that somewhat greater strength is secured, but the labor is heavier, and the first method is more convenient in making the trusses, laying the second floor, and fitting the openings in the first story.

Intermediate between the trusses the rafters are spaced 2 feet apart, supported by the plate and purlin. Studding in the second story are spaced 4 or 6 feet apart, and diagonal

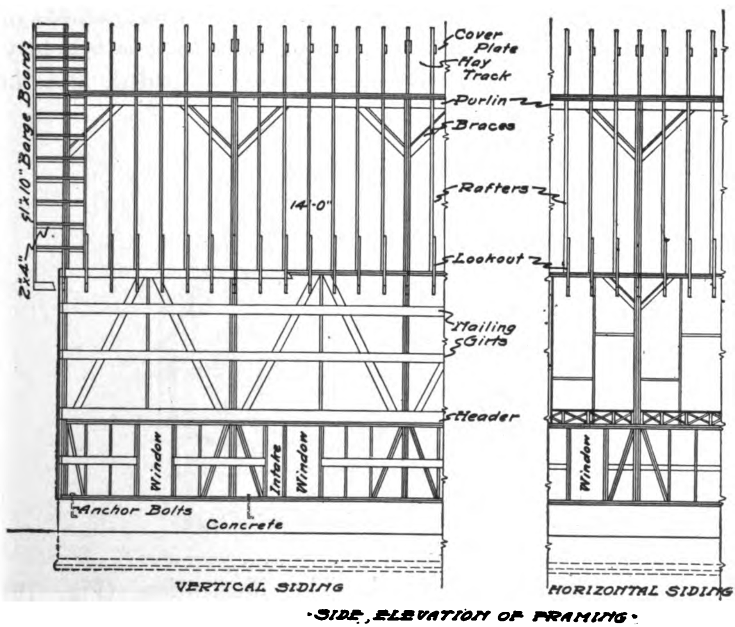


FIG. 78.—Side elevation of framing, Shawver frame.

braces used in every bent. Nailing girts of 2 by 6 are placed horizontally outside of the studding, trusses, and bracing, to receive the vertical siding. The frame can be adapted for horizontal siding by omitting the nailing strips, and placing the studding not over 3 feet apart. End framing consists of a truss, filled in with vertical supports, and the nailing pieces, as shown in the illustration.

The advantages claimed for the Shawver or plank truss frame are: There are few trusses to build and erect; the construction is strong, and can be used on a barn 40 or even 42 feet wide; the barn is simple to construct; there is a saving of lumber over the timber frame construction.

Wide Barn Framing.—It has been said that the limit of width for the braced rafter frame barn is 36 or 38 feet, and for the Shawver frame, 40 or 42. The common method of securing a wide barn has always been to add lean-to sheds on one or both sides of the barn. The wide barn, to be satisfactory, must be specially designed for the width intended, and the

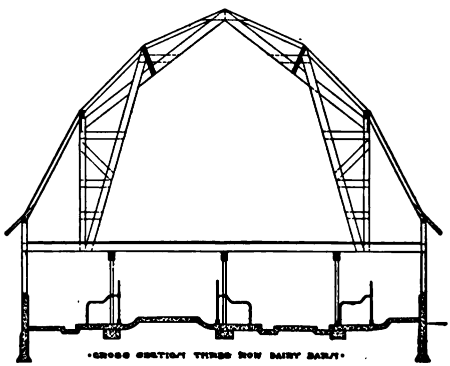


Fig. 79.—Cross-section of wide barn

lean-to is not recommended. The illustration (Fig. 79) shows an Iowa barn designed for 3 rows of stock, which has proven satisfactory. The loft, however, is self supporting through 36 feet or less.

Gothic Roof Framing.—The Gothic roof barn is popular because of the large loft space, strong construction, and novel appearance. No framing pieces project into the loft. The cost of construction of the Gothic roof is greater than for the other types, due to the amount of cutting and fitting required.

The shape of the roof is a pointed arch as usually built,

and is secured by taking a radius equal to three-fourths the width of the barn to find the curve of the rafters. The center is taken at a point 3 or 4 feet below the level of the plate, and an arc is described through the plate and the center of the barn at the ridge. The point of meeting of the two arcs drawn determines the ridge and the shape of the entire roof. The lookout is a reverse curve, on a 5-foot radius, and fits smoothly into the rafter curve.

There are two methods of building the rafters. The

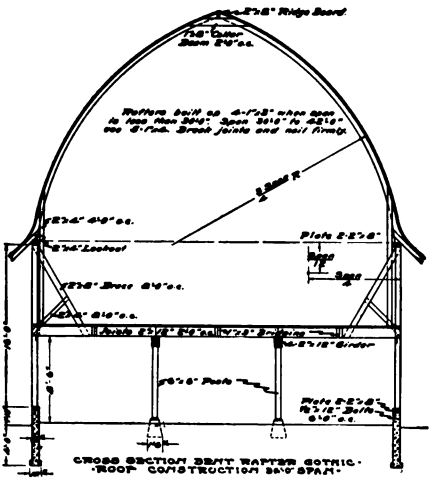


FIG. 80.—Cross-section of bent rafter (Gothic) type of construction.

common method is to lay out the shape of the rafter on a smooth surface, and to fit 1 by 4 pieces to the form. Five or six pieces are bent to shape and nailed to form a rafter of the correct shape and strength. The rafters are spaced 2 feet apart in the building, and tied at the ridge. To prevent spreading, short braces are placed between the plate and the floor. The end framing and wall construction are the same as in the braced rafter barn.

The former method was to saw 1 by 10-inch boards to the proper curvature and build up to three or four thicknesses of

boards, breaking joints. Short boards were used. This method was laborious and wasteful.

Round Barn Framing.—The framing of the round barn is similar to that for the braced-rafter barn. The members of the frame converge to the center, making the round frame very strong. The two-slope gambrel roof is most often used. Since the round barn will be about 60 feet or more in diameter, longer length lumber is required in the roof frame. Since the

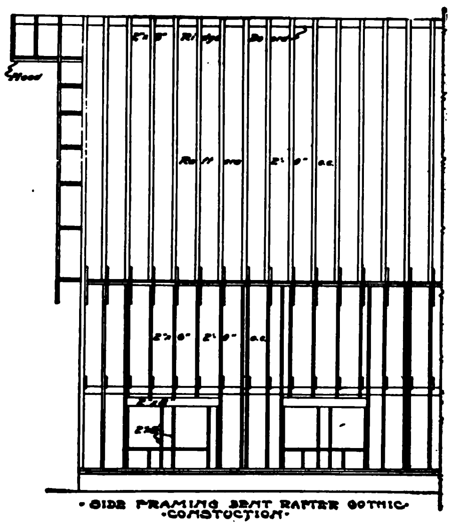


Fig. 81.—Side elevation of framing, bent rafter construction.

framing parts become closer together as they approach the center, there is more material in the round barn frame than is necessary for strength. The reader should not confuse the round barn roof frame with the Gothic frame, which is used on rectangular barns.

Framing Details.—The best indication of a good builder or a good designer is the manner in which he handles the details of building construction. In the plan the details should show the exact sizes of material and the manner in which the

pieces are put together. The builder and framer should be able to read the detail drawings, and know how to apply them to the structure.

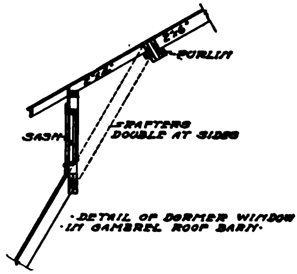


FIG. 82.—Detail of dormer window for gambrel roof.

It would be impossible to secure the best results in the construction of a building from plans, unless the details are carefully worked out. It is possible in this text to give only the details which apply in particular to this discussion. Every plan, however, has certain points of construction that should be worked out in detail by the designer.

CHAPTER XI

BARN VENTILATION

FREQUENT reference has been made in preceding chapters to the need of adequate ventilation in the various barns. It is comparatively easy to admit a sufficient quantity of air into a building, if that were the only problem. The value of a ventilating system, however, lies in its ability to admit fresh air into the barn without drafts, and without reducing the temperature below normal. Old barns built with loose-fitting windows and with cracks between the pieces of siding admitted fresh air, but in severely cold or windy weather such barns were not comfortable for the stock. Modern barns, with good construction, do not admit air through various parts of the building, and are likely to be under-ventilated, unless special provision is made for adequate ventilation.

Ventilation has not been developed to an exact science which can be theoretically applied to every case and made to work. The factors of climatic conditions, prevailing winds, cubic space, number of stock, and proximity to timber or a body of water all have an influence, which makes every barn a special problem of ventilation. The suggestions here given apply to the general case, and on the average have been found to give the best results.

Definition.—Ventilation is the process of introducing fresh air into a building, in sufficient quantities, and removing the products of respiration, maintaining the air at a certain healthful standard. The following discussion considers the methods necessary to secure " controlled " ventilation.

Purposes of Ventilation.—The purposes of ventilation are to provide fresh air, carry away odors, remove carbon dioxide, and carry away moisture.

Fresh air is necessary because it contains the element oxygen, which is necessary to sustain life. A dairy cow will breathe considerably more than 200 pounds of air in twenty-four hours, or more than twice the weight of feed and water consumed. The blood is purified by passing through the lungs, where the oxygen burns the waste products of the body.

The odors must be removed from the stable if sanitary products are to be secured, and the barn made a pleasant place in which to work. A well-ventilated barn is noticeably free from the odor of animal bodies, silage and manure.

Carbon dioxide is almost entirely lacking in fresh country air, but in every cubic foot of breathed air there are about 72 cubic inches of carbon dioxide gas. At the same time the amount of life-giving oxygen has been reduced by about 100 cubic inches, through breathing. An excess of carbon dioxide causes sluggishness, decreases production, and lowers the vitality of the animals. The same effect of sluggishness and indifference may be observed in a group of people in a badly ventilated hall or building.

An average cow exhales as much as $11\frac{1}{2}$ pounds of water in one day, through the breath and the pores of the skin. Dry air when breathed gains 50 to 75 cubic inches of moisture in each cubic foot of air breathed. The result of excessive moisture is to cause frosty walls and noticeable dampness in the barn. Badly ventilated barns are steamy on cold mornings. The stock are more susceptible to colds and pneumonia when kept in a damp barn.

COMPOSITION OF FRESH AND BREATHED AIR

	Dry Fresh Air per cent	Breathed Air per cent
Oxygen	20.94	16.16
Carbon dioxide	.029	4.38
Nitrogen, etc	79.03	74.46
Moisture	....	5.00

The above average composition of dry fresh air and air once breathed shows a loss of about 4.75 per cent of oxygen, and a gain of almost the same amount of carbon dioxide. There is an increase of moisture of about 5 per cent.

Amount Breathed.—Each animal housed in barns breathes approximately the amounts of air shown by the following table:

Animal	Per 24 Hours, Cu.ft.	Per Hour, Cu.ft.	Per Min., Cu.ft.
Horse	3401	141	2.3
Cow	2804	116	1.9
Pig	1103	46	.76
Sheep	726	30	.5

Standard of Purity.—The purity of air is usually indicated by the carbon dioxide content. Pure country air contains only about 4 or 5 parts of carbon dioxide in 10,000 parts; very bad air may contain 60 or 70 parts in 10,000. It is assumed that stable air should not contain more than 15 parts of carbon dioxide in 10,000. If the carbon dioxide content of once-breathed air is 4.38 per cent, as indicated in the above table, the breathed air of the stable must be diluted with fresh air to reduce the content of carbon dioxide from 4.38 parts per 100 to 15 parts per 10,000. If this is done it will be necessary to introduce 96.7 per cent of fresh air to each 3.3 per cent of breathed air. In other words, each breath drawn should contain not more than 3.3 per cent of once-breathed air, and at least 96.7 per cent of fresh air.

To maintain this condition in the stable, it is evident that much more air will have to pass through the stable than is actually breathed. The following table shows the amount of air required for each animal:

AMOUNT OF AIR REQUIRED

Animal	Air per Minute, Cu.ft.
Horse	71
Cow	59
Pig	23
Sheep	15

Rate of Flow.—If the amount of air required in the barn is known, the next problem is to design a system of flues to introduce this amount. The area of the flues can be determined if the rate of flow is known, or assumed. The rate of flow will vary with the length of flues, weather conditions, and temperature. As a basis for the design, the rate of flow through well-designed flues in the average barn is assumed as 15,000 feet per hour, or 250 feet per minute. The actual flow will often exceed this amount, and under certain conditions the flow will be small, or even reverse the normal direction.

Motive Powers.—If it were possible to use mechanical means to provide a forced circulation of air through the flues, the rate of flow could be accurately figured. However, in barns the only practical means of securing circulation is by natural forces. The three motive powers depended upon are wind pressure, wind suction, and temperature difference.

By wind pressure is meant the force of the wind against the side of the building, by which the air is forced into the intakes, or fresh-air flues. The pressure is noticeably strong when a heavy flow of air is striking the barn, and in cold weather it may be found necessary to close some of the intakes on the windward side. The calculation of the wind pressure as it affects the air flow cannot be determined theoretically. The force due to a 20-mile velocity wind, however, is about 2 pounds per square foot.

Wind suction is produced by the action of the wind across

the top of the ventilating shaft, or through the cupola. The action is similar to that of air passing across the top of a chimney. As long as there is a normal unobstructed passage of air, the draft will continue, and will vary with the velocity of the wind. Trees or buildings tend to interrupt the passage of air, and in certain cases there may be a back draft produced in the flue. The suction is so irregular that it cannot be depended upon at all times to produce circulation in the building. The length of the flue has an influence on the suction, the longer flue producing the greatest draft. The flues for foul air should be about 20 feet long or longer to maintain the normal flow of air.

Temperature difference has the greatest influence on the circulation of air in barns. Warm air is lighter than cold air, due to the expansion with heat, and the warm stable air tends to rise. Each degree Fahrenheit of temperature rise causes a change of volume equal to $\frac{1}{491}$ of the original volume. The raising of the temperature 1° F. in a space of 500 cubic feet will force approximately 1 cubic foot of air out of an opening which might be provided. In zero weather the temperature difference between stable air and outside air is between 40 and 50°. The difference in weight between the warm and cold air is about 10 per cent under these conditions, and if suitable flues are provided, there will be a constant outflow of air. As the air passes from the stable to the outlet it is cooled, and the decrease in volume tends to create a partial vacuum in the flue, which increases the flow.

The combined action of these three motive powers may be expected to produce a rate of flow as given above, of 250 feet per minute, if the flues are properly placed and designed. Since the ventilating systems used in farm barns are not automatic in action, some attention will need to be given as weather conditions vary. In extremely cold weather it may be necessary partially to close the flues, to prevent excessive air movement and a consequent drop in the stable temperature. In mild, calm weather the forces may not be sufficient to ventilate the barn and windows will have to be opened. The design

of the flues is based upon general conditions, and personal attention will have to be given at times.

Systems of Ventilation.—The two recognized systems of barn ventilation used in the United States and Canada are the King and Rutherford systems. Window openings, holes in the wall, and hay chutes as outtake flues are not recognized as representing any system of controlled ventilation.

Rutherford System.—Rutherford of Canada designed and installed a system of ventilation in some of the Canadian Experimental barns. Although this system is not widely used in barns in the United States, it is used with success in Canada. Hog houses are often ventilated in this country with the Rutherford system.

The distinguishing features of the Rutherford system lie in the installation of the flues. The fresh-air inlets are near the floor line of the stable, and the foul air is taken through flues from the ceiling line. All flues are fitted with regulators or adjusters, in order partially or completely to shut off the flow of air in severe weather. It was assumed that the effects of impartial ventilation were not as injurious as the results of very low temperatures in the stable. The illustration shows the essential features of the Rutherford system. The area of the flues is made about 50 per cent smaller in the Rutherford system, as compared to the figures given later for the King system.

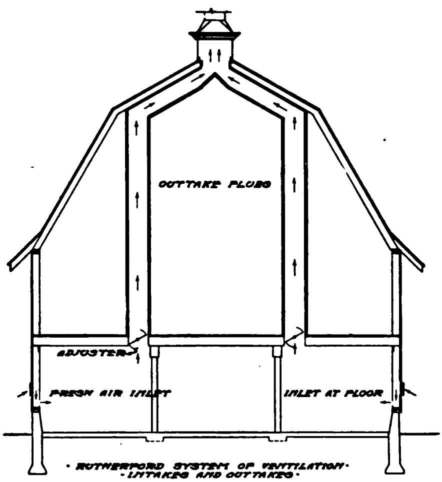


Fig. 83.—Barn section showing Rutherford ventilating system.

King System.—Practically all of the work done on barn ventilation in the United States at present is based upon the

experiments of the late Professor F. H. King of the Wisconsin Experiment Station. There have been some adaptations of King's recommendations, but in general the systems of ventilation sold under the various trade names are considered as coming under the classification of the King system.

The essential features of the King system are fresh-air flues, entering at the ceiling line, and foul air outtakes extending from near the stable floor to the roof. A discussion of the construction and parts of the King system is given in the following paragraphs.

Area and Size of Flues.—To determine the area of the flues in the King system, it is only necessary to know the volume of air required and the rate of flow. The rate of flow has been assumed as being 15,000 feet per hour, or 250 feet per minute. The cubic feet of air for each animal was given in a previous table. To find the area, divide the number of cubic feet per minute required by 250, the velocity of flow, and the result will be the area of flue, in square feet. In terms of square inches, the area of flue required per animal is as follows:

Animal	Area in Sq. in.
Horse	40
Cow	34
Pig	13
Sheep	9

The above figures are for average-sized animals, and if any change is made, the area should be increased somewhat over the figures noted, to allow for varying results. The total area of flues is found by multiplying the above figures by the number of head of each class of stock housed. The total required area will then be divided by the number of intake flues and outtakes decided upon.

Intake Flues.—The intake flue of these systems should be designed to bring fresh air into the stable and prevent the

escape of warm air. They are built into the side walls of the building, entering at or near the foundation line, and opening into the stable at the ceiling, in front of the animals. The flues are made to trap the warm air in the building by making the inner opening at least 4 or $4\frac{1}{2}$ feet of vertical distance above the outside opening.

The thickness of the intake flue is limited by the thickness

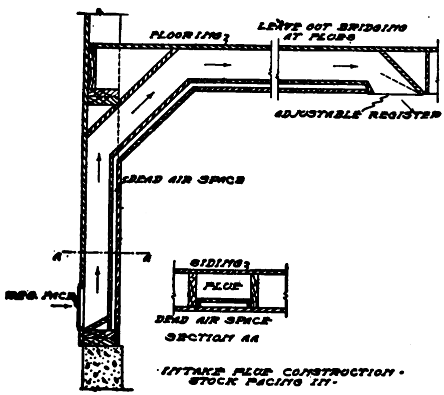


Fig. 84.—Air intake for a King ventilating system when the animals face in.

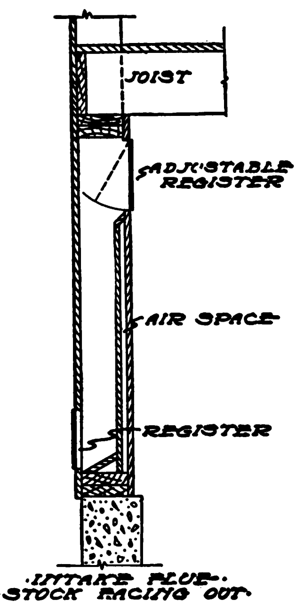


Fig. 85.—Air intake for King ventilating system where the animals face out.

of the wall. With 2 by 8-inch studding in the wall, the actual thickness is about $7\frac{3}{4}$ inches. The stable side of the flue should be insulated from the warmth of the stable to prevent condensation of moisture. This insulation is made by means of a dead air space, and double covering, which will further reduce the thickness of the flue. With a 6-inch wall, the flue will be

about 4½ to 5 inches thick, and in an 8-inch wall the effective thickness will be only 6 to 7 inches. The width of the flue may be from 10 to 16 inches. If the flues are correctly spaced, they will not need to be wider than 12 to 14 inches. The size of the flue is increased at the entrance, to offset the loss of area due to the screening, and the size of the stable opening is increased to avoid possible drafts. The turns in the flue tend to reduce the velocity, and these points should be made larger.

Spacing of Flues.—In order to provide a good circulation

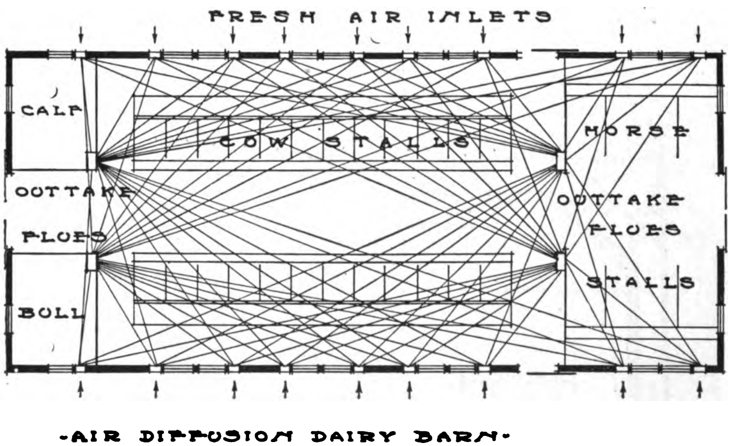


Fig. 86.—Showing diffusion of air with a well-planned ventilating system.

of air in the barn, the intakes should be widely distributed, and the total area should not be afforded by only a small number of flues. In general the flues will be spaced 6 to 10 feet apart, and not over 10 feet in any case.

Construction of Flues.—If of wood, the flues are built into the barn at the time the walls are constructed. The opening for the flue is framed as for any other opening in the wall. The studding may form the sides of the flue, and the siding may be used for the outer covering. Inside the stable there should

be two thicknesses of material to insulate the flue from the stable, one thickness of material being placed inside the studding and the other layer over the studding, as shown in Fig. 83. The turns should be smooth, in order to maintain the velocity of the air, and sheet metal should be used to secure a gradual deflection. When the stock faces the center of the barn, the flues are carried to the center between the joists. The outside face of the flue should be covered with a galvanized screen, to keep out birds, trash, and dirt. The inside opening should be covered with an adjustable register, which can be opened or closed to regulate the flow of air.

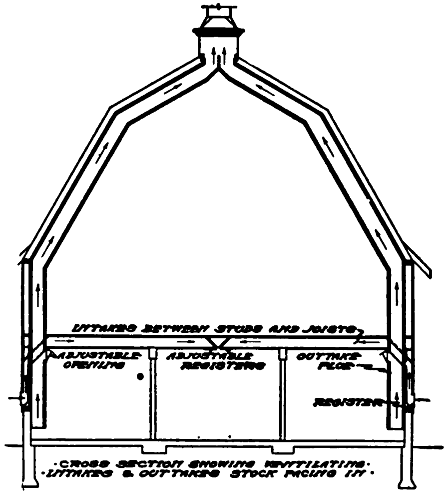


Fig. 87.—Outtake flues for King ventilating system when animals face in.

Metal flues as a part of the complete system may be used for the intakes. They are smooth, easily installed, and efficient. Basement barns, or old barns to be remodeled, present difficult problems in the installation of flues. The principal problem is to trap the warm air in the barn, and yet secure as direct passage as possible of the fresh air.

Outtakes.—The outtake flues extend from near the floor of the stable to the ridge of the roof. The flues are taken from the rear of the stalls, in order to avoid carrying the foul air past the heads of the animals. The location should be made to keep the flues away from a silo chute, or door, which might interfere with the correct action of the outtake. In the stable the flues must not block a stall, pen, or driveway. In the loft, the flue must be kept 5 feet away from the carrier

track, in order not to interfere with the passage of a fork load of hay. In the "face-in" arrangement of the stock, the flues can be carried up inside the roof rafters without obstructing the loft. The object of the outtake-flue construction is to afford a direct passage of the air from stable to roof. The flues are carried from the floor line to prevent excessive cooling which might result from taking the air from the upper part of the stable.

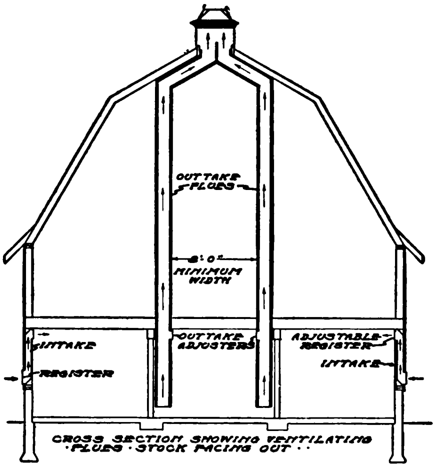


FIG. 88.—Outtake flues for King ventilating system when animals face out.

Spacing of Outtakes.—The outtakes are comparatively few in number as compared with the intakes, the exact number depending on the facing of the stock, and length of barn. If the stock face the outer wall, there is usually one outtake for each cupola, although they may be in pairs—one on each side of the driveway. In the "face-in" plan the outtakes are in pairs, two flues to each ventilator. In short buildings, not more than 34 feet long, one cupola and one or two flues are sufficient. Barns up to 74 feet long require two cupolas, from 75 to 100-foot barns should have three cupolas, and in longer barns they should be spaced about 25 feet apart. Care should be taken to locate the flues with reference to the floor plan to avoid wasting space.

Size.—The area of each flue is determined by dividing the total area required by the number of flues to be installed. One outtake will, in general, care for five or six intakes. Square or round flues are the most economical and efficient, though a rectangular shape may be preferred to suit conditions. The

maximum size for any one outtake should be about 2 square feet. The flues are enlarged at turns or bends to keep the effective area the same throughout.

Construction.—The outtake flues may be built of wood or metal. The wood flues are lower in cost, and when properly built should last fully as long as the metal flues. The construction consists of two thicknesses of matched lumber, with building paper between, to make the flue tight. Moisture-resisting wood, such as white pine or cypress, is preferable. The flues should be built inside the studding and rafter line, and not

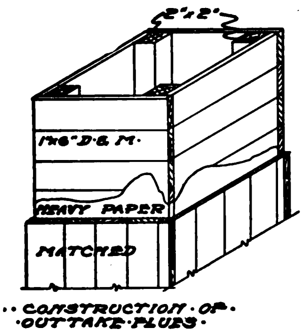


Fig. 89.—Detail of outtake flue construction.

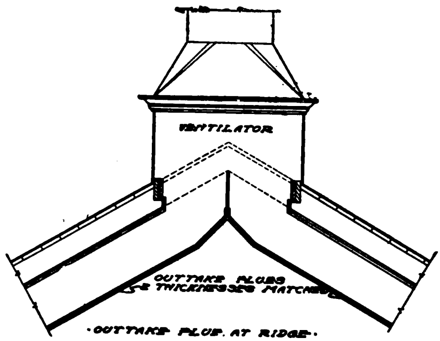


Fig. 90.—Detail of outtake flue at ridge of barn.

between the framing members; if they are placed next to the sheathing, they will be cold, and will tend to frost, and fail to carry away the moisture. If built inside the rafters, there is a dead air space formed that aids in insulating the flue. The outtakes should in all cases be made tight from the stable to the ridge, and be tightly boxed to the cupola. Openings in the loft destroy the draft, and make the system inefficient.

Metal flues are satisfactory if properly constructed. Home-made metal flues are likely to be unsatisfactory, for the reason that they are not properly insulated. The flues will be cold in the loft, and the moisture in the outgoing air will condense on the metal, and run back into the stable. If metal is used, it should be made especially for the ventilating system.

of rust-resisting, galvanized iron or steel, and thoroughly insulated.

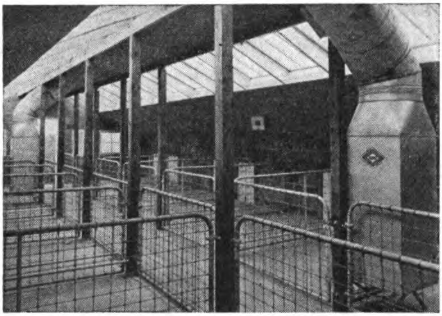


FIG. 91.—Metal outtake flue in hog barn.

Cupolas.—The size of the ventilator should be determined, so that the same, or a greater area is secured in the drum of the cupola, than in the outtake flues. The object of the cupola is to protect the opening of the flue from the elements, keep out birds, prevent back drafts as far as possible, and assist in drawing the foul air from the barn. The well-designed steel ventilator accomplishes these objects. The home-built wood cupola accomplishes none of the objects satisfactorily. For any other purpose than ornamentation, the wood cupola should be replaced with the more modern steel cupola. The size is usually specified by the diameter of the drum, from which the area can be determined.

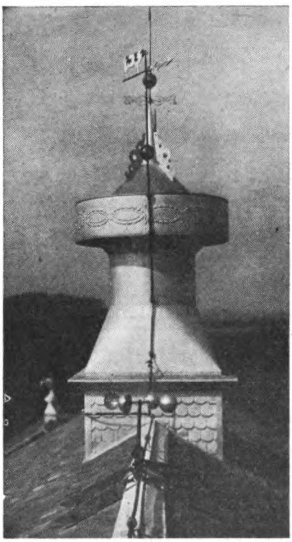


FIG. 92.—Metal ventilating cupola in place.

The steel cupola is a conductor of electricity, and if a

copper cable conductor is fastened to the base, and extended a few feet into the ground, an efficient lightning rod is obtained.

Temperature Control.—In the Rutherford system the temperature is controlled by opening or closing the flues, and reducing the circulation. If the King system is installed, as discussed above, there is little danger of low temperatures in the stable of the well-built barn. If the barn becomes too warm, the air should be taken from the ceiling, as the warm air rises. To do this, there should be a trap door in each outtake, at the ceiling line, which may be opened. It was formerly thought that the air at the floor line contained the greater part of the carbon dioxide. In the well-stocked barn the air is in constant circulation, and the amount of carbon dioxide at the ceiling seems to be about the same as at the floor. The reason for extending the flues to the floor is to trap the warm air, and prevent too low a temperature in the stable.

Failure to Ventilate.—The foul-smelling barn, frosty and damp walls, and sluggish, indifferent stock are indications that the barn is not properly ventilated. Barns with no provision for ventilation show the above conditions in a majority of cases. Makeshift ventilating systems, such as the use of hay chutes for outtakes, louvre windows, or wood cupolas for outtakes, and windows for intakes, cause large numbers of failures, and is a wrong attitude toward ventilation. The barn which has a complete system of ventilation installed is properly ventilated in most cases. The failures which have occurred can be traced to faulty placing of the parts, too large an amount of cubic space per animal, or the housing of very young, or only a few head of stock in the barn. If these causes for failure are removed, there is little doubt that the system will operate, provided some personal attention is given.

Ventilation Tests.—It is possible to determine the efficiency of a ventilating system by means of certain tests. The average reader is interested principally in the design of a system for best results, rather than the theory of the test.

The main points of a ventilation test are mentioned here. If the student reader has access to the necessary instruments, it is suggested that a test be arranged.

The apparatus needed for a test of a ventilation system is: Air meter; wet- and dry-bulb thermometers; and instruments for determining the carbon dioxide content of the air.

The data secured should cover the measurements of all parts of the system, the theoretical design, to check the actual installation, and remarks with reference to conditions in the

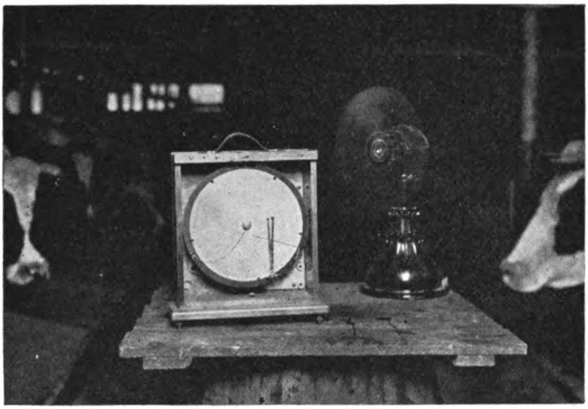


Fig. 93.—Recording thermometer used in connection with ventilation studies.

stable. The temperature should be determined in the stable, and outside. By means of the wet bulb, and handbook tables, the relative humidity can be found. Samples of stable air taken in different parts of the stable will show the carbon dioxide content.

The results of the test will show the rate of air flow, the inside and outside temperatures, and the degree of purity of the stable air. Such a test should show the faults, if there are any, in the design of the system, indicate the remedy for trouble, and is of value as a guide to future installations of similar character.

Problem of Ventilation.—In order to show the manner in which the requirements for a ventilation system are ascertained, the following problem is given: Assume a general-purpose barn, with 30 head of dairy cows, 10 horses, and 15 calves. Find the number and size of intakes, outtakes, and cupolas.

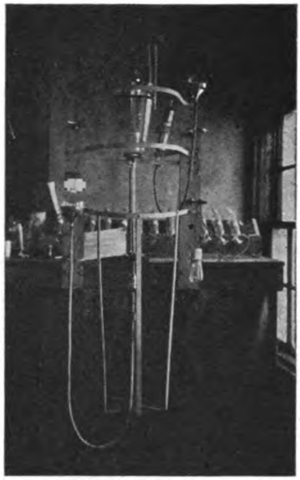


FIG. 94.—Apparatus for determining carbon dioxide content of air.

Each dairy cow requires a fresh air supply of 59 cubic feet per minute. For 30 head the amount is 1770 cubic feet per minute. Ten head of horses, requiring 71 feet each, gives 710 cubic feet. Fifteen calves will need as much air as about half that number of cows, or 30 times 15 or 450 cubic feet.

The total air flow will then need to be 2930 cubic feet per minute. Assuming that the average flow of air through the system will be 250 feet per minute, 2930 divided by 250 will equal approximately 12 square feet, area of flues.

If the thickness of the wall permitted a 6-inch flue for the intake, and they are assumed to be the average width of 14 inches, each flue affords 84 square inches of intake. Approximately twenty intakes are required, or ten on each side of the barn.

Six outtake flues, each affording 2 square feet area, or a size of 12 by 24 inches each, provides sufficient area of foul-air outtakes. The size and number might be varied, but the area should still be 12 square feet. If the stock face the center, each pair of flues will be carried to one cupola.

Three cupolas are required. The standard size of 24-inch drum, with an area of about 3.14 square feet, is insufficient. The next larger size of, say, 28 inches, will then be used. Two 24-inch and one 30-inch ventilator might also be used, and the size of the outtakes varied accordingly.

CHAPTER XII

HOG HOUSES

THE hog house was almost the last of the principal farm buildings to be developed, but in recent years much attention has been given to hog-house construction and sanitation. The change has been from the poorly built, dark, cold, and dirty structure, to the modern, sanitary hog house. Hogs are more numerous than any other class of farm animals, and yield the quickest returns. On January 1, 1919, there were 75½ million hogs on farms, with a farm value estimated at more than 1½ billion dollars.

Proper housing results in a more sanitary farmstead, and a more healthful place for the hogs. Fewer losses result from disease and more pigs are raised per litter; two litters per year are possible, with early spring farrowing. Labor saving results from good practical houses. For pure-bred breeding stock, it is essential that the stock be handled in good quarters.

Essential Features of Good Hog Houses.—The Iowa Experiment Station has listed the essential features of hog houses as follows:

1. Warmth.
2. Dryness.
3. Light, and direct sunlight.
4. Shade in summer.
5. Ventilation.
6. Safety and comfort.
7. Convenience.
8. Serviceability.
9. Sufficient size.

10. Durability.
11. Reasonable first cost.
12. Low maintenance.
13. Pleasing appearance.

The essential features listed above may be classified under the general essentials of sanitation, planning, and construction.

Sanitation.—It is generally understood that for success with hogs, it is necessary to pay careful attention to the sanitary requirements of the hog house. Little pigs must be kept warm and dry. Plenty of light and especially direct sunlight is essential in the house, in the spring and fall farrowing

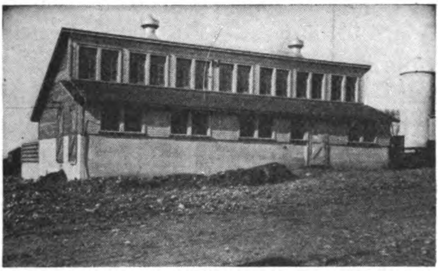


FIG. 95.—Half monitor type of hog house.

seasons. Proper drainage of the floor, pen, and feeding yard is necessary. Mud holes, wet bedding, and muddy feeding yards waste feed, and promote unhealthful conditions. Ventilation is necessary in the winter season. The essentials of sunlight and ventilation are of such importance that they will be discussed more fully in the following chapter.

Planning.—The essentials of size, convenience, safety, and comfort are all possible by careful consideration of the plan. Size of pens, width of alleys, and equipment for the safety and comfort of the stock have been largely provided for in the more widely used plans.

Construction.—Durability, appearance, maintenance cost, and economy of construction are largely problems of construction. If the best principles of construction are followed, good

results will be secured—the actual construction of the hog house is comparatively simple.

General Problems.—Since there are a large number of cases in which hog raising is one of the principal projects of the farm, further attention should be given to some of the details relating to housing and equipment. Among them are feed storage; artificial heat; outside runways; feeding and watering equipment; and hog-house equipment.

Feed Storage.—In the permanent type of hog house a feed storage room should be included. For the individual houses, it is desirable that the feed supply be near at hand, and provision should be made to handle the feed by the wagon load. Mixed feed and purchased concentrates should be stored near where they are to be used. For the large feeder it is well to have the corn crib close to the feeding yard.

Artificial Heat.—A heating system is not generally included in the plan. If pure-bred hogs are raised, it may be desirable to install heating equipment. A small stove in the feed alley or store room may be the means of saving chilled pigs. In a few cases steam or warm-air heating systems have been installed in the hog house. A lighted lantern in the individual house may be needed in early spring at farrowing time.

Outside Runways.—Regardless of the type of house, it is desirable to provide individual pens or runways outside the building for the sow and litter, or for the herd boar. For little pigs, a separate pen, or creep, either inside the house, or in the yard, makes it possible to begin separate feeding at an early age.

Feeding and Watering.—The self feeder has proven satisfactory for feeding growing pigs, and its use has eliminated much of the labor of feeding. The feeders may be made to hold a small load of feed at one time, and slight attention is needed, except to keep the feed supplied. Running water to the hog house, and to each pen, greatly reduces the labor of caring for the stock.

Hog-house Equipment.—Modern methods in the care and handling of hogs, especially breeding stock, call for the use

of manufactured equipment. Steel fixtures are superior to wooden equipment from the standpoint of appearance, sanitation, and convenience. The interior equipment is in many respects similar to the steel equipment for the dairy barn. Steel panel for pens allows the passage of sunlight, and aids sanitation. Movable panels permit of throwing several pens together into a feeding pen. Swinging front panels over the trough make it convenient for feeding. The same types

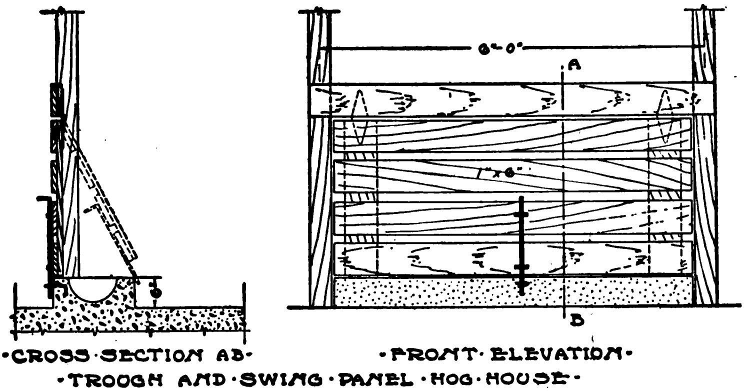


FIG. 96.—Pen trough and swinging panel.

of litter and feed carriers and ventilators used in the barn are suitable for the hog house. In addition, hog troughs, swill carriers, guard rails and drains are essential in the best equipped hog houses.

MOVABLE HOG HOUSES

The movable house is widely used, and successful under a variety of conditions. It may be the only type used on many farms, and on others it is used to supplement the permanent or centralized house. The type is of sufficient importance to justify a discussion of the advantages, and the construction in some detail.

Advantages.—The advantages of the movable houses as given are in comparison with the centralized or community

type. In many cases the use of both types is recommended, one being used to supplement the other.

The location of the small house may be changed to meet conditions. Pastures may be changed, shelter provided for hogs harvesting corn, or following cattle, and isolation is quickly secured. For sows at farrowing time, it may be desirable to move the shelter to a quiet location. There is less danger of crowding and fighting when the houses are separated.

Sanitation is promoted with the movable house, since surroundings may be changed; the herd is separated; and sick animals isolated. As feeding is usually done outside the

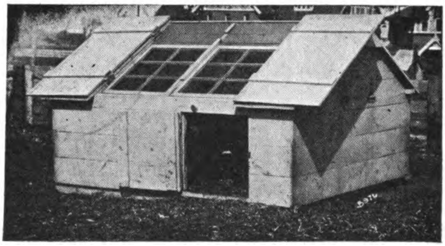


Fig. 97.—The Iowa movable hog house.

house, there is little danger of the pens becoming foul and damp.

The construction of the movable house is simple, and the building can be done in the winter season, or at other times when the farm help is available.

For renters, beginners, and owners of small herds, the movable house affords a good shelter for a small outlay of money. It is possible to begin operations on a small scale, and gradually increase the capacity of the houses as the herd justifies added equipment. For the renter, the houses may be taken when the tenant moves from farm to farm.

Disadvantages of the Movable Type.—When used exclusively for housing, the small houses have certain disadvantages, but these disadvantages are principally arguments for the community house, and will be discussed as such.

Types of Movable Houses.—There is a wide variation in the shape of the movable house, and some difference in the shape and arrangement and location of doors and windows. Most of the common types are satisfactory, however. The most common types are the gable-roof, combination, and A-shaped houses.

Gable-roof House.—This type has a vertical side wall to a height of about 2½ feet, and thus utilizes the full area of the floor. The roof is of two equal pitches. End doors are provided for entrance, and large doors are placed in one slope of the roof, for airing and sunlight. The side walls may be

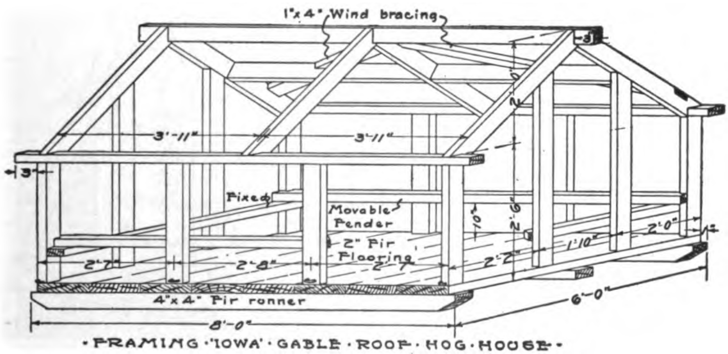


FIG. 98.—Framing details of Iowa movable hog house.

nailed tightly to the studding, or they may be hinged at the top to open outward, to provide shade in the summer.

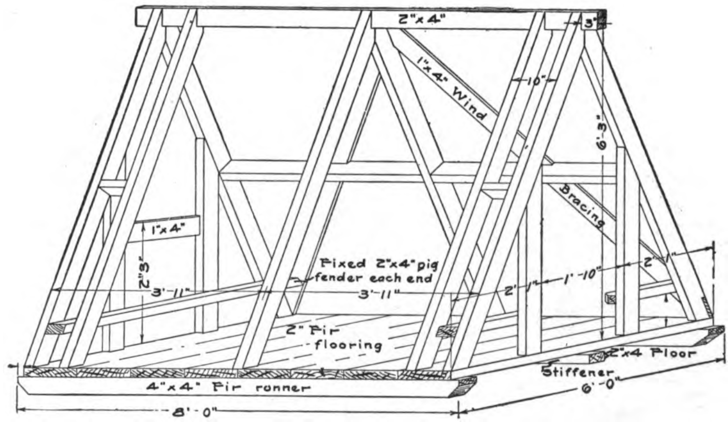
Combination-roof House.—The object of the roof with unequal pitches as used in this house is to afford more head-room and more direct sunlight when the house is faced to the south. The construction is not essentially different from the gable-roof house.

A-shaped House.—This type of house does not have side walls, but the A-shaped roof is carried to the floor. This simplifies the framing, and reduces the amount of material needed. The angle of the roof with the floor affords a space which protects the little pigs from being crushed by the mother.

The sides may be hinged at the side or top, forming doors. The door hinged at the top provides shade, while the doors hinged at the side permit of better airing and direct sunlight.

Construction.—Except for the minor variations mentioned the construction of all of the movable houses is practically the same. The size of movable house found most satisfactory is 6 by 8 feet.

The runners or the sills of the house should be made of 4 by 4-inch fir, cypress, or other moisture-resisting wood,



·FRAMING 'A' SHAPE·HOG·HOUSE·

FIG. 99.—Framing details of "A" shape hog house.

beveled at the ends for easy moving. For the floor 2 by 12-inch lumber is necessary, the planks being nailed directly to the runners. One-inch material does not afford a rigid floor. The floor is omitted in the very cheap houses, but this is not recommended.

Framing is entirely of 2 by 4-inch material, usually yellow pine. Enough framing should be used to insure a rigid, strong construction, and one which can be safely moved.

One thickness of covering is all that is usually needed. Eight or 10-inch shiplap is the best material for the covering, though plain boards with battens may be used. Further

protection may be secured by covering the house with prepared roofing, but this is not often done.

The doors consist of entrance, shade, and roof doors. The entrance should be 2 by $2\frac{1}{2}$ feet for average stock, and larger for heavy stock. The shade doors are hinged at the top and open outward. Roof doors should be in the east or south side of the house, to take advantage of the direct sunlight. All doors should be well braced, and fastened with heavy hinges.

Guard rails are necessary to prevent the pigs from being crushed against the wall by the heavy sow. Two by 4 or

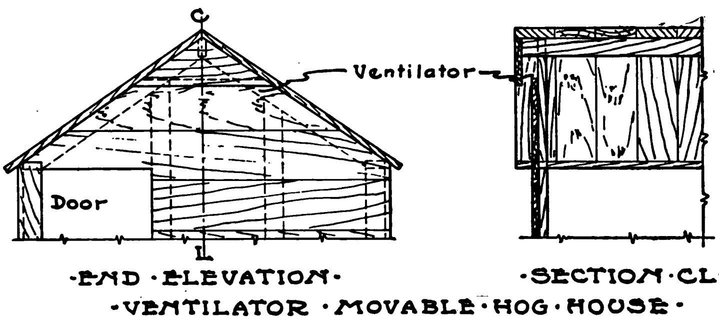


FIG. 100.—Detail of ventilation for Iowa movable hog house.

2 by 6-inch material is set 6 inches above the floor, and the same distance from the wall.

The sanitary requirements of light and ventilation are not so easy to secure in the small house. Ventilation is secured by means of a small opening under the ridge, protected by a board nailed to the projecting roof board. Small gable doors in the end of the house may be left open in mild weather. Direct sunlight may be secured by leaving the roof doors open. In the gable or combination roof houses, window sash may be fitted into the door frame.

From 350 to 425 board feet of lumber is required for the construction of the movable house, in addition to the necessary hinges, nails, and bolts. The cost will vary from \$20 to \$30 per house.

Community Hog Houses

The development of the farmstead group with its well-planned and permanent buildings favors the large, permanent type of hog house. Fall litters, scarcity of labor, and the increase in the pure-bred hog business has tended to promote the use of the community house. Careful attention to planning in recent years has resulted in well-planned, sanitary, convenient, and good-appearing hog houses.

There are several advantages in favor of this type of house as compared with the small movable house, and these points will be discussed in the following paragraphs.

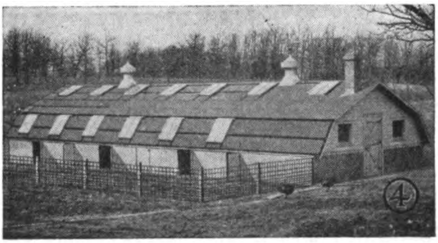


Fig. 101.—Gambrel-roof type of hog house.

Durability.—The use of concrete, tile, and brick is possible in the large hog house; heavier framing and better workmanship are usually secured; concrete floors and foundations are also possible.

Compact Housing.—Close attention to the herd is possible in the community house. If necessary the herdsman can remain at the building during the farrowing season. Feeding operations can be carried on within the one shelter, and feeding floors, feed rooms, and feeding equipment may be used to better advantage. Steel equipment, litter carriers and ventilators are possible in the compact arrangement of the community house.

Sanitary Features.—The concrete or tile floors, and possibly the masonry walls of the community house favor sani-

tation. The use of steel pens and troughs is better than the cheaper equipment necessary in the small house. Windows may be located for a maximum of sunlight on the farrowing

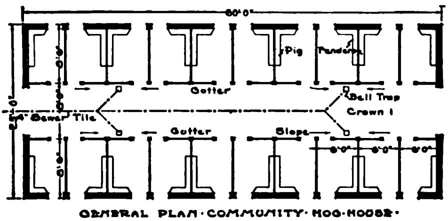


FIG. 102.—Floor plan of community hog house.

pens, and the result is warmth, dryness, and cleanliness not possible in the individual house. Artificial heat may be installed for use in the early spring.

Greater Production Possible.—The community houses enable many farmers to raise two litters per year, which is

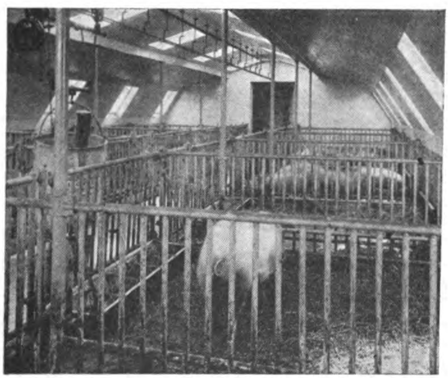


Fig. 103.—Metal pens, community hog house

considered profitable by a majority of hog producers. The better sanitation and greater conveniences prevent excessive losses of young pigs.

Appearance and Construction.—The community house justifies more care in planning and construction, and better materials. The result will usually be improved appearance and better construction. Feeding floors, individual runways, farrowing pens, and other features increase the value of the community house. The selling value of the farm and of breeding hogs is increased if the building is well made, and well equipped to exhibit the stock.

Location.—The hog house should be farther from the house than the other buildings, to avoid objectionable odors. Nearness to cribs, pastures, and cattle feeding yards should be considered. Slope of the lots and location for protection

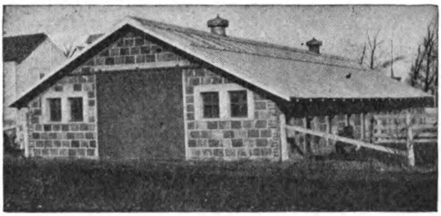


Fig. 104.—Iowa sunlit hog house.

are important. The setting of the building for sunlight will be considered later.

Width.—The best width of the hog house is that necessary to accommodate two rows of pens, with an alley between. The average pen is 8 feet long, and the alley 4 or 8 feet wide, according to whether or not it is to be used for a driveway. The usual width of house will vary from 20 to 26 feet. If the wider house is used, the driveway may be used as a feeding floor, or may be divided into temporary pens for farrowing. The alley provides a suitable place in which to feed young pigs.

Length.—The length of the hog house will, as in the other buildings, depend on the number of head of stock. Besides the desired number of pens, the house should have a feed room and store room, or a place for the necessary equipment. Com-

mon lengths are from 30 to 60 feet, with from eight to eighteen farrowing pens.

Pens.—The most widely used pen is 6 feet wide by 8 feet long, though occasionally it is 7 or 8 feet each way. Small pens with removable partitions may be thrown together after the farrowing season, and used for feeding pens. The front of the pen next to the feed alley is taken up by the trough and gate, the rear half of the pen being used as a nesting place.

Each pen should have a door to the feed alley and one opening into a yard or exercise pen. In the south-front house the north door is sometimes omitted, and the north wall banked. Fenders, trough, gates, doors, and panels constitute the features of the farrowing pen.

Doors and Gates.—Inside gates should be 2 feet 4 inches clear width. All gates should open in the same direction, and in the same relative part of the pen, being made of the same material as the pen partitions. Outside doors should open from each pen in most cases, and should be made of matched lumber, firmly braced; the door frame may be of wood or masonry. Partition gates, made to slide upward, are sometimes used to connect pens. In this way a creep may be made for feeding young pigs separate from the sows. Gate and corner posts are 4 by 4 wood, or may be made of concrete.

Troughs.—The best troughs are 6 to 8 inches high, and about 14 inches wide, either of V-shape or flat-bottom. Steel troughs are light and sanitary. Concrete is a good trough material but is heavy to handle. Wood troughs are easily made, but lack permanence, and are harder to keep clean. The usual length for farrowing pen trough is 3½ feet.

Panels.—Panels in the front of the pen and the pen partitions should be tight near the floor, with a total height of about 3 feet. The front panel over the trough should be arranged so it will swing inward over the trough for convenience in feeding, and must be braced so it will not be pushed out The cross panels which separate the pens should be hinged or bolted, in order that two or more pens may be thrown together if desired.

Wood pens have been used almost entirely because of the low cost. When strongly made, and kept clean, the only objection to the wood panels is that much sunlight is lost from the pens. Steel pen panels are light, clean, and permit the passage of most of the sunlight through the bars. For high-grade or breeding stock the steel equipment is economical.

Fenders.—There should be provision made in every farrowing pen to protect the little pigs from being crushed by the sow. A fender or guard rail next to the wall will prevent the pigs from being crushed by the mother against the panel or wall. The fenders may be made of wood, iron pipe, or masonry. A 2 by 4-inch piece makes a satisfactory fender.

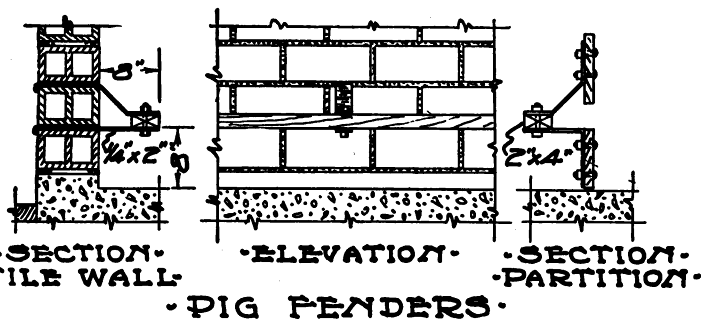


Fig. 105.—Detail of pig fenders.

In any case the projection should be placed 6 inches from the floor, and extending 6 inches into the pen. Masonry fenders may be cast or placed as an integral part of the wall.

Drains.—The use of traps and closed drains is not recommended in the hog house, because of the trouble due to clogging. The best drainage is secured by sloping the floor about $\frac{1}{4}$ inch to the foot toward the gate, and draining the alley by a depression in the floor.

Nesting Place.—The concrete or tile floor is objected to by many hog men because it is likely to be cold and damp. This cannot be remedied by bedding, as it is not desirable to have a deep litter on the floor at farrowing time. The usual

method of providing a warm nesting place is to make a wood overlay of inch boards, which can be removed when the pigs are a few weeks old. The overlay is about 4 by 5 feet in size.

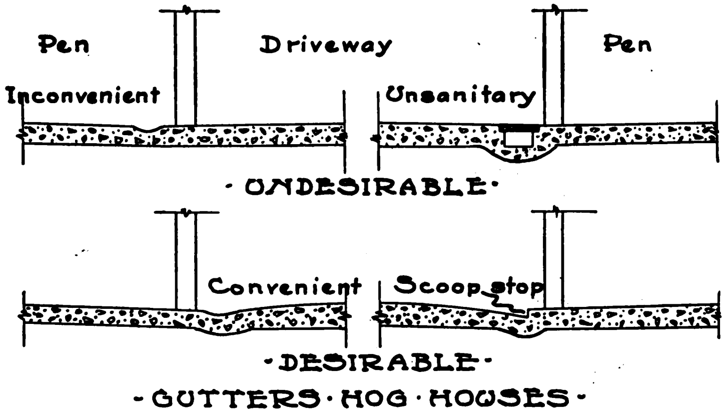


FIG. 106.—Good and bad types of gutters for hog houses.

Permanent nesting places of wood blocks or cork brick are used in some houses, and give good results.

HOG-HOUSE CONSTRUCTION

The construction of the hog house and outbuildings presents a simpler problem than the construction of the barn. The plans and construction will be easily understood after a study is made of barns. The foundation is lighter, and the framing and masonry is less complicated. Regardless of the shape or style of the house, the construction is similar.

Foundation.—The footing should extend to firm soil, and below the frost line if possible. From 2 to 3½ feet below grade is usually sufficient. Concrete or tile is the best material to use. The foundation should be carried above grade to a height of from 6 inches to 1 foot, if the walls are frame. The width of foundation is 6 to 8 inches.

Floors.—The best floors are made of 4 inches of concrete, or of a 4-inch layer of hollow tile covered with ¾ inch of con-

crete. If an overlay is used for the nesting place there should be no objection to the masonry floor. Wood and dirt floors should not be used.

Walls.—The walls of the community house may be of concrete, hollow tile, or frame. If of frame, the studding are

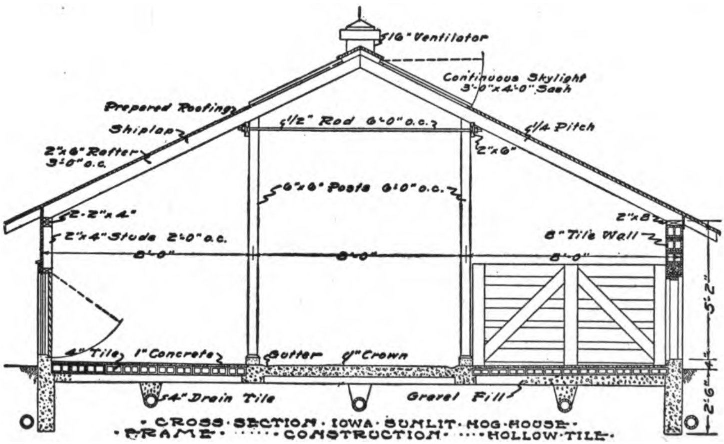


FIG. 107.—Cross-section of Iowa sunlit hog house.

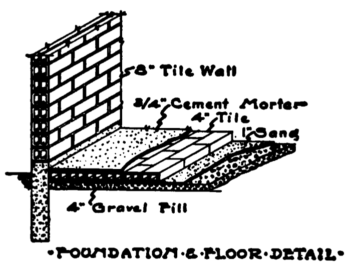


FIG. 108.—Details of walls and floor.

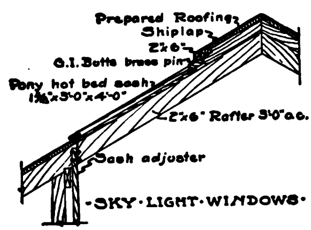


FIG. 109.—Details of sunlit or skylight window.

2 by 4-inch material with 1-inch siding. The tile are laid to form either a 5 or an 8-inch wall, the latter being warmer and stronger. The door and window frames may be made of brick, or closed tile, if carefully laid to give a straight, smooth opening. Concrete or concrete blocks are likely to be somewhat

cold and damp unless made with an air space. The side walls are from 4 to 5 feet high in ordinary construction.

Roof Framing.—The roof is made of 2 by 4 or 2 by 6-inch rafters, with sheathing and shingles or prepared roll roofing, the amount of bracing depending on the particular style of house selected. Enough framing should be used to prevent sagging or swaying. If masonry walls are used, the plate should be bolted to the walls at intervals of 6 or 8 feet. In case windows are placed in the roof, the framing must be made to receive the sash.

Types of Community Houses

The general division of types depends upon how the house is placed for sunlight. The two groups are the "North and South" houses, which set with the long axis to the north and south, and the "East and West" type, which fronts toward the south. A complete discussion of sunlight is given in the next chapter. The type of house is usually designated by the roof shape. Those in common use are: Shed roof; combination-roof; monitor; gambrel; half-monitor; and gable-roof houses.

Shed Roof.—This type is usually a one-row, low-cost house, 12 to 14 feet wide. The roof consists of a single pitch, and the windows are in the south, or front wall. The rear wall is about 5 feet high, and the front wall is 6 to 9 feet in height.

Combination Roof.—The combination roof has two slopes of unequal length. It is used for the one-row or small two-row house. Under most circumstances the combination roof has no advantage over the gable roof, except under certain conditions for lighting.

Monitor Roof.—This house is set north and south, and has no windows in the roof. The monitor or center portion is made higher, and a row of windows placed on each side of the monitor, for the purpose of getting direct sunlight. The house is likely to be cold because of the height of the ceiling. There is no advantage in this type over those discussed later.

Gambrel Roof.—The gambrel roof, with two slopes on each side, affords very good lighting arrangements, has low head room, and provides a good appearing roof. There are four rows of windows in the roof, providing light in the pens throughout the day. From the standpoint of appearance the house fits well into the farmstead group, with the gambrel-

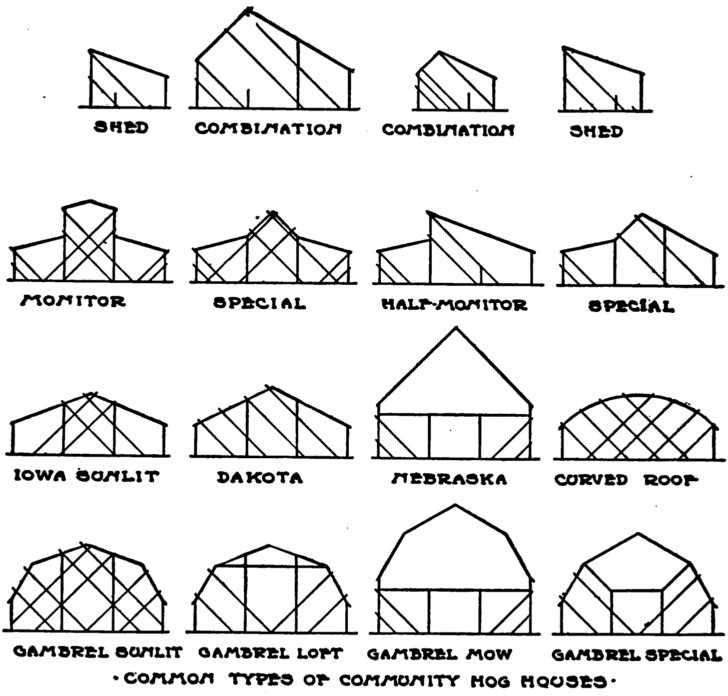


FIG. 110.

roof barns. This type is a recent development, and its use is increasing.

Half-monitor Roof.—This type is very popular as a south-front house, and is the most widely used house in the Middle West. The side walls are 4 to 5 feet high, and the total height of the house is 12 to 14 feet. The exact proportions depend

upon the location of windows for sunlight. There are two rows of windows, one row in the upper and one row in the lower south wall.

Gable-roof House.—The two-slope or gable-roof house is simple in construction, and is adaptable to a variety of conditions. This type, together with the gambrel and half monitor represent the most popular and best types of community houses. In the two-row house the height is 12 or 13 feet to the ridge. The roof is usually made $\frac{1}{4}$ pitch. The side walls are 4 or 5 feet high. Ventilation and lighting can be easily controlled.

There are three styles of the gable-roof house that have proven so popular that they should be considered briefly They are the " Iowa Sunlit," the " Nebraska," and the " Dakota," or modified Iowa type. The Iowa sunlit house is the most popular gable-roof house, and is set with the long axis north and south, a continuous row of windows being placed in each slope, so there will be direct sunlight in the pens throughout every clear day. This house was developed by the Iowa Experiment Station.

The Nebraska house is set north and south, but the walls are made 6 to 7 feet high, with all windows in the side walls. The roof is made at a half pitch, and feed and bedding storage is provided in a loft.

The Dakota type has the long axis to the east and west, and has two rows of windows in the south slope. The doors may be omitted from the north wall, and the wall banked for warmth.

CHAPTER XIII

HOG HOUSE SANITATION

Of the various points mentioned as essential for the modern hog house, the sanitary requirements are the most important. It is possible to raise good hogs without high-priced or nice appearing equipment, but it is not possible to do so without careful attention to the requirements of sunlight, ventilation, and comfort.

Most of the essentials of sanitation and comfort depend

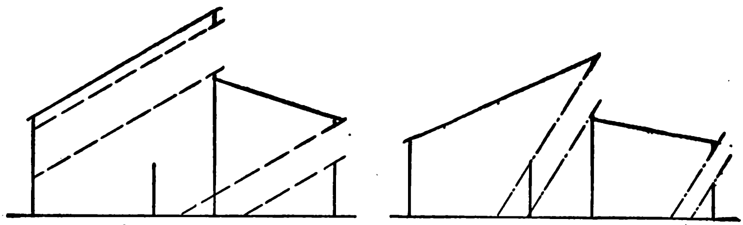


Fig. 111.

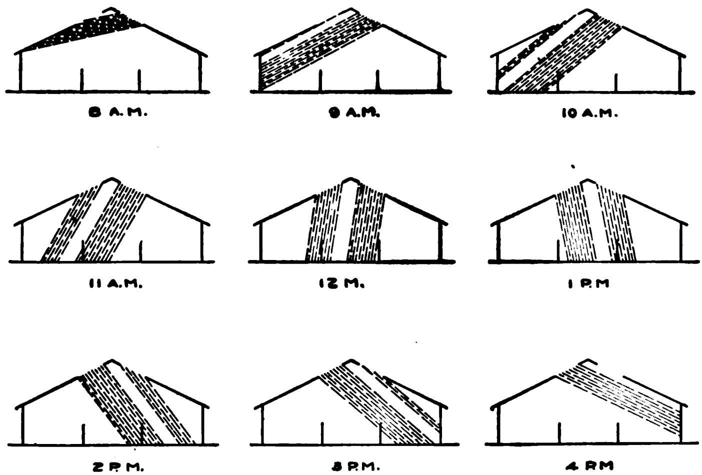
wholly or in part upon the correct introduction of direct sunlight into the house. Hogs kept in houses not provided with sufficient and correctly located windows are subject to colds, pneumonia, and disease.

The United States Department of Agriculture and the Iowa Experiment Station have worked out the problem of sunlight so completely that the builder can properly locate the windows in the hog house.

Individual Hog House.—It is more difficult to secure satisfactory sunlight in the small hog house than in the community type. The large doors allow the entrance of sunlight

if they are turned toward the south. For severe weather, it may be possible to place window sash in the door frames to admit sunlight. The gable-roof house, with roof doors, is the best from the standpoint of lighting. Sunlight may be secured for a period of about five hours per day in this type if the doors are in the south side of the house.

Community Hog House.—The community houses are divided into two general classes, so far as lighting is concerned.



·POSITION·OF SUNLIGHT·IN·IOWA·SUNLIT·HOG·HOUSE·MARCH·8, 1915·
·AMES,·IOWA·42°·N.·LAT.·93°·W.·LONG.·

Fig. 112.

One group includes all types with the long axis to the north and south, and receiving the direct sunlight through the windows in the side walls and roof. The second group includes those houses which face the south, and have all the windows in the south roof or wall.

North and South Houses.—The houses included in this group are the gable-roof house, with windows in the roof or wall, the gambrel-roof house, with windows in all slopes of the roof, and the full monitor house, with windows in the upper and lower walls.

The Iowa sunlit type of gable-roof house has a continuous row of windows on each side of the roof. Every part of the floor receives direct light at some time during each clear day. The west pens get the benefit of the morning sun, and the east pens are directly lighted in the afternoon.

The windows in the gambrel-roof house are not continuous, but are provided in each slope of the roof, and the pens are very well lighted throughout the day. The full monitor house does not afford light to as good advantage as the other types. The two-story houses have all the windows in the side wall, but the light strikes some windows during most of the day.

In each case the sunlight reaches the pens early in the day, and continues to strike some part of the floor of the farrowing pens throughout the day. There is no variation of lighting during the season, except as the days become longer, in the spring, the length of time during which the house is lighted is increased.

East and West Houses.—The houses set to face the south include the shed, combination, gable, and half-monitor roof houses. In each case the windows are placed in the south side of the house, and receive direct sunlight through about five hours per day.

The shed roof is usually narrow, and the windows are all placed in the side wall. The alley may be at the front or rear of the house, depending on the best arrangement for sunlight, as discussed in the following pages. For certain conditions, it will be found that the combination-roof house will afford more direct light in the pens than the shed room. There is one row of windows in this type of house, in the south slope of the roof.

It is often desired to use the Iowa type of gable-roof house, but with the long axis east and west. In this case two rows of windows will be placed in the south roof to light the two rows of pens.

The half-monitor house should have a row of windows in each section of the south wall. The total height of the house will depend on the window location for best lighting.

Principles of Window Location.—The location of the windows in the south-front hog houses depends on the two factors of latitude and time. It is essential that the maximum of

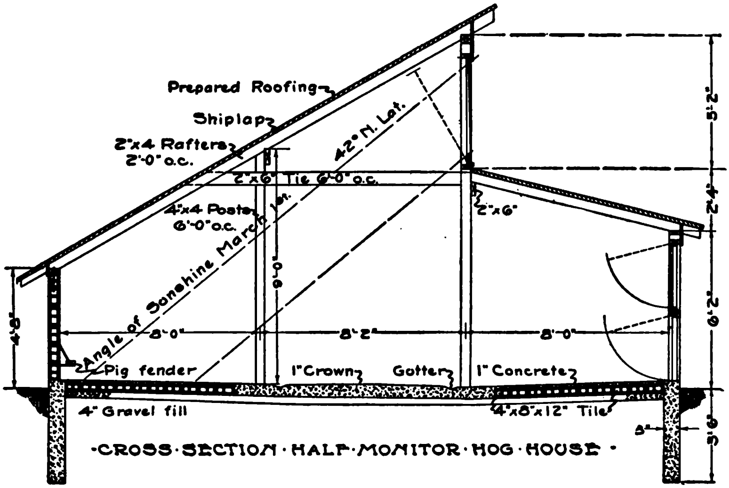


Fig. 113.

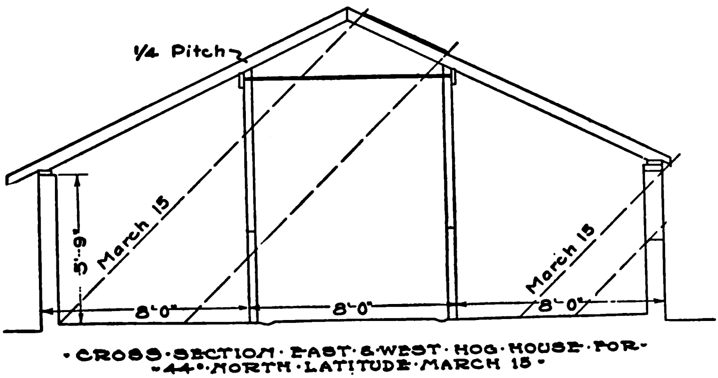


Fig. 114.—Cross-section showing sunlight in house, March 1st, 44° N. latitude.

light enter the house at farrowing time, especially if the farrowing date is in the early spring or late fall.

It is commonly understood that in the Northern Hemi-

sphere the sun appears lowest in the south about December 22, and more nearly overhead about June 22. If the shadows at noontime are noted at these different seasons, it will be seen that a long shadow is cast in the winter and a short shadow in the summer. This indicates that the angle between the sun's rays and the earth in the latitude of the United States is amaller in winter and larger in summer. This angle varies not only with the season, but with the latitude. The sun appears more nearly overhead in Florida than in Minnesota on April 1st. For each degree of latitude, and each week or month there is a distinct difference in the angle of the sun's rays, which have been worked out in the form of tables.

The following table gives the angle of sunlight at 42½ degrees north latitude, from January to April:

Month	Angle	
	Degrees	Minutes
January 1	24	30
February 1	29	30
March 1	39	50
April 1	52	0

The map shows the latitude covering the area of the United States. The figures range from 26° to almost 50°. The spring farrowing season will ordinarily range from February 1 to April 15. With these two factors in mind it is possible to locate the windows so the sunlight will be most effective at the time it is most needed. An analysis of houses built without regard to location of windows shows the

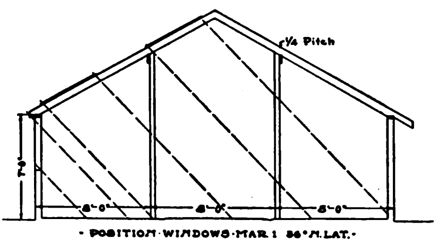


Fig. 115.—Sunlight in hog house, March 1st, 36° N. latitude.

result of poor planning, as the light does not strike the pens at farrowing time.

The sunlight table herewith is taken from the records of the U. S. Naval Observatory, as given in Farmers' Bulletin 438. In this table, the authors have reduced all figures to a basis of height of window necessary to throw direct light a distance of 8 feet back of the window at noon. For example: Suppose the figure were desired for 42° north, on March 1, noon. By referring to the column headed March 1, and in the space opposite 42°, the figure 6 feet 10 inches is given. This is the height necessary for the top of the window to throw light a distance of 8 feet into the building. For other distances back from the wall, at 42°, and March 1, it is only necessary to construct a reference triangle, drawn to scale, with 8-foot base, and 6 feet 10 inches vertical leg. The hypotenuse

SUNLIGHT TABLE

Month	January		February		March		April		May
Day	1	15	1	14	1	15	1	15	1
34°	5′ 2″	5′ 8″	6′ 6″	7′ 6″	9′ 1″	11′ 3″	14′ 3″	18′ 1″	22′ 11″
35°	5′ 0″	5′ 6″	6′ 3″	7′ 3″	8′ 9″	10′ 10″	13′ 7″	17′ 4″	21′ 10″
36°	4′ 10″	5′ 4″	6′ 0″	6′ 11″	8′ 5″	10′ 4″	13′ 1″	16′ 7″	20′ 9″
37°	4′ 8″	5′ 2″	5′ 10″	6′ 8″	8′ 1″	10′ 0″	12′ 7″	15′ 10″	19′ 10″
38°	4′ 5″	4′ 11″	5′ 7″	6′ 5″	7′ 10″	9′ 7″	12′ 1″	15′ 2″	18′ 11″
39°	4′ 3″	4′ 9″	5′ 4″	6′ 2″	7′ 7″	9′ 4″	11′ 8″	14′ 6″	18′ 0″
40°	4′ 1″	4′ 7″	5′ 2″	6′ 0″	7′ 4″	9′ 1″	11′ 2″	13′ 11″	17′ 1″
41°	3′ 11″	4′ 4″	4′ 11″	5′ 10″	7′ 1″	8′ 9″	10′ 9″	13′ 4″	16′ 5″
42°	3′ 9″	4′ 1″	4′ 9″	5′ 7″	6′ 10″	8′ 5″	10′ 5″	12′ 10″	15′ 9″
43°	3′ 7″	3′ 11″	4′ 7″	5′ 5″	6′ 7″	8′ 1″	10′ 0″	12′ 4″	14′ 7″
44°	3′ 5″	3′ 9″	4′ 5″	5′ 3″	6′ 4″	7′ 10″	9′ 8″	11′ 10″	14′ 5″
45°	3′ 3″	3′ 7″	4′ 2″	5′ 0″	6′ 1″	7′ 7″	9′ 4″	11′ 5″	13′ 10″
46°	3′ 1″	3′ 5″	4′ 0″	4′ 9″	5′ 10″	7′ 3″	9′ 0″	11′ 1″	13′ 4″
47°	2′ 11″	3′ 2″	3′ 9″	4′ 7″	5′ 6″	6′ 11″	8′ 8″	10′ 7″	12′ 9″
48°	2′ 9″	3′ 0″	3′ 6″	4′ 5″	5′ 3″	6′ 7″	8′ 4″	10′ 2″	12′ 3″
Day	11	26	11	28	14	29	14	30	15
	Dec.	Nov.		October		Sept.		August	

The figures in the body of the table show height of top of window for sunlight to fall 8 feet 0 inches inside of wall in which window is placed, at noon. The unit, 8 feet 0 inches, for shadow length, is taken for convenience, because it is the length of the standard farrowing pen.

will be parallel to the sun's ray. All rays are then parallel to the first, and for any distance back from the wall, a similar triangle may be drawn to locate the top of the window required. In a like manner, the reference triangle for each degree latitude, and each date, may be constructed.

Locating Windows on Plan.—The windows should be placed to throw direct rays of sunlight to the rear of the farrowing pen at the beginning of the farrowing season, in order that

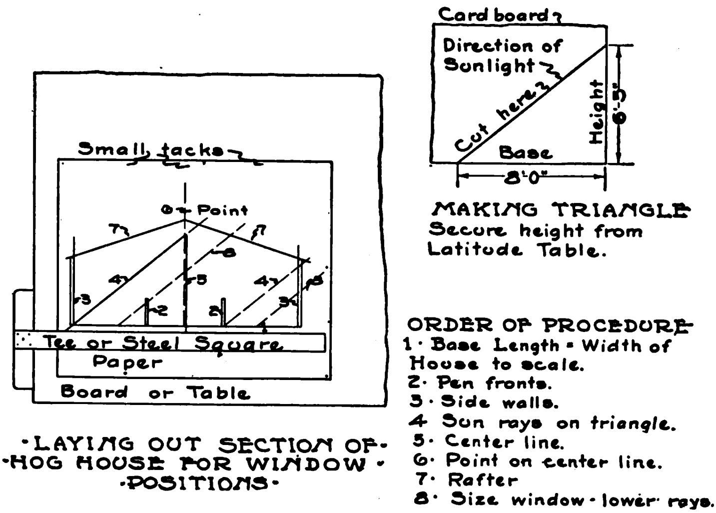


FIG. 116.—Illustrating method of locating windows in hog house.

there will be some light in the pens during the month following. The following operations are necessary to locate the windows on the plan:

1. Place sheet of paper on drawing board.
2. Determine farrowing date and latitude.
3. Lay out a partial cross-section of the house, showing width of alleys and pens, side walls and floor.
4. Refer to the sunlight table, and determine the height of window to throw light back 8 feet.
5. Construct reference triangle, with 8-foot base, and

erect a perpendicular line at the end of the base line equal to window height. Complete the triangle by drawing the hypotenuse.

6. Draw a line parallel to the hypotenuse of the reference triangle, from the floor line, at the rear of the north, or back pen. Extend this line across the paper so it will cut the wall or roof. Now complete the sectional view of the house desired, putting in wall height and roof slope. The point

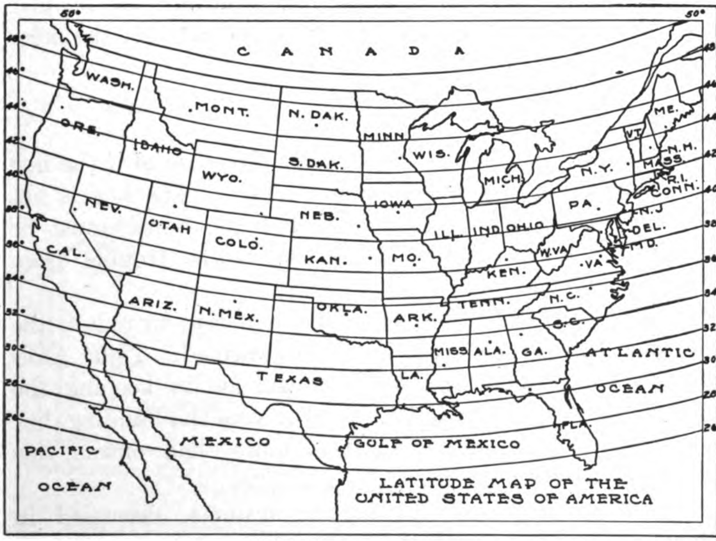


FIG. 117.—Latitude map for the United States.

where the line drawn cuts the wall or roof is the correct location of the top of the window.

7. Repeat 6, drawing the line from the rear of the front pens to locate the second row of windows. It sometimes happens that the wall plate or structural members interfere with the correct location of window, as determined. It may be necessary to revise the plan of the building to avoid this.

Size and Kind of Windows.—The windows should be fitted with plain, double-strength glass, and should be comparatively

long and narrow. The most common size of metal window in use is one giving an effective glass area of 20 by 28 inches. Hothouse sash 3 by 4 feet for roof windows are satisfactory. The larger the window, the less proportion of light is cut off by the sash and the window frames.

In sections where hail is common the roof windows should be protected by a heavy wire mesh. All windows should be arranged to open in mild weather, for ventilation. Excess light through skylight windows in hot weather may be prevented by shades, or by straw placed on boards over the cross ties.

Ventilation

The removal of foul air and moisture is essential if the hog house is to be kept healthful and sanitary. The hog is not well protected by natural covering, and the house must be kept warm. Dampness in the house causes trouble from pneumonia and colds.

The height of the house should be kept low, to reduce the amount of cubic space that must be warmed. Tight walls and close-fitting doors and windows will aid in keeping the house warm. The roof windows tend to cool the building, but the warmth of the direct sunlight more than offsets this tendency.

Both the King and Rutherford systems, discussed in Chapter XI, are used in hog houses. They have been modified to some extent to meet the conditions in the hog house.

The Rutherford system is easier to install in the house, and appears to give good results. The short length of flue, and the difficulty of constructing intakes in the low wall lessens the value of the King system. Since the usual construction omits ceiling under the rafters, and because of the roof windows, the air is not greatly warmer at the ceiling than at the floor line. The motive powers of wind pressure and wind suction do not act with full effect, since the hog house is low and usually protected. The temperature difference is not so marked as in the farm barn.

The Rutherford system provides a ventilator outlet at the roof and a ventilator at the ridge. The intakes may be at the wall plate, or a distance of about 4 feet from the ground. This height is sufficient to prevent back draft, and the incoming air does not strike the stock directly.

The King system takes the foul air from the floor line, and the fresh air entrance is made somewhat above the wall plate. The flues should, in all cases, be tight, and fitted with adjusters. Direct drafts on the stock are dangerous.

Either of the two common systems may be used, and either

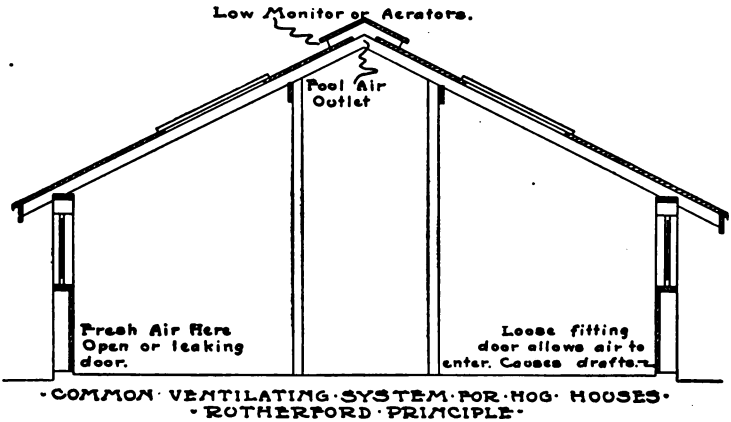


FIG. 118.—Common ventilating system for a hog house.

is preferable to no system at all. The same general principles of ventilation apply to hog houses as to barns. (Chapter XI.)

Design of System.—Each full-grown pig will breathe about 1100 cubic feet of air in twenty-four hours, or 46 cubic feet per hour. In order to maintain the correct standard of purity it is necessary to supply 23 cubic feet per minute. The number of head of stock in the hog house will vary, and the flues must have attention, and be regulated according to the number of head housed. For average conditions there should be a 12-inch diameter cupola for each 20 feet of length of the

two-row house. The intakes should have an equal area. In mild weather some of the windows should be opened. In cold weather it will be necessary partially to close the flues. The hog house should never be allowed to become hot, damp, and steamy. Personal attention is necessary if the ventilating system is to work efficiently.

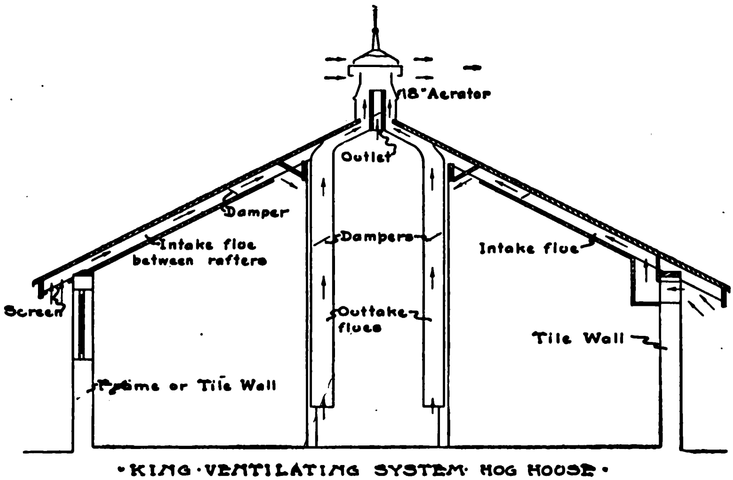


FIG. 119.—The King ventilating system adapted to a hog house.

Other Items of Sanitation.—The features of sunlight and ventilation are the biggest items in securing a sanitary hog house. The problems of drainage, floors, and equipment have been discussed elsewhere in the text. It is also important that feeding equipment, yards, and feeding floors be thoroughly cleaned at frequent intervals, and every possible precaution taken to prevent disease and unhealthful conditions.

CHAPTER XIV

POULTRY HOUSES

The farm flock must be well housed and cared for, and not allowed to shift for itself, if results are to be secured in egg and poultry production. The modern poultry house should have facilities for feeding, exercise or scratching, nesting and roosting.

Location.—The poultry house should be located on well-

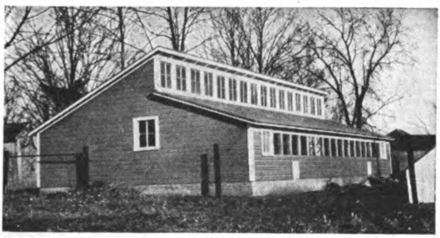


FIG. 120.—The Iowa half monitor type of poultry house.

drained, porous soil. For best lighting the house should be set with the long axis east and west. Shelter against winter winds and storms by windbreaks or other buildings is desirable, while in summer there should be as much air movement around the house as possible. The poultry house may be located closer to the dwelling than the other buildings, since the women of the household usually care for the flock. The poultry should be kept away from the feed lots, barns, and cribs.

Size.—Three to 4 square feet of floor space, depending on the breed, should be allowed for each bird, when groups of from 15 to 50 are grouped in one flock. Modern poultry houses

are built in units of length of 8, 12, 16, and 20 feet. The use of the open-front house in recent years has tended to increase the width of the house. The width ranges from 14 to 24 feet, depending upon whether the front of the house is partially closed, or open. Each bird should be allowed from 12 to 20 cubic feet of space. With more than this space the houses are likely to become cold.

Construction.—The average poultry house is of a simple, light construction, not essentially different from the other small structures. The principal points in the plan and construction discussed here are those generally followed, and apply to practically all of the types in common use.

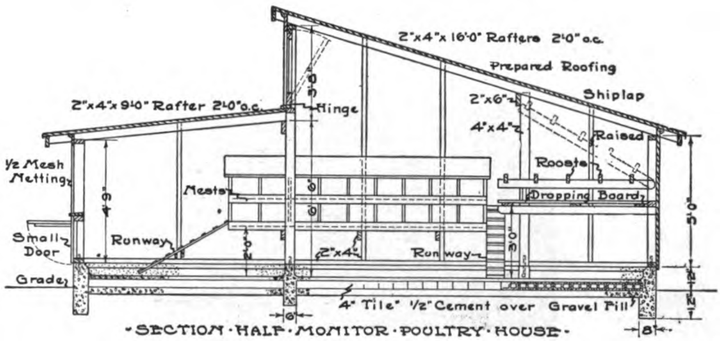


FIG. 121.—Cross-section of Iowa half monitor poultry house.

Foundation.—A masonry wall, 6 inches wide, and extending 12 to 18 inches below the ground line, is sufficient for the poultry house foundation. The footing should be widened somewhat, and steel reinforcing near the bottom of the foundation wall will prevent cracking and upheaval due to frost action. New reinforcing rods, or old steel bars or rods will serve to strengthen the foundation. The wall should be carried 6 inches or more above the grade line. Masonry is recommended in preference to wood sills, for all but the movable colony house.

Floors.—Wood or dirt floors should not be used in the poultry house, on account of unsanitary features, rodents,

and insect pests. Either the concrete or hollow tile floor may be used, though the concrete floor has the disadvantage of being cold and damp. The liberal use of clean litter will partly overcome this objection. The floor should be made 3 to 4 inches thick. The tile floor is warmer and dryer than the concrete, and is made by making a gravel fill to a depth of 4 inches or more, over which 4 by 8 by 12 tile are laid in a sand cushion. One inch of concrete is used to cover the tile, and give a smooth floor. The tile may be defective without damage to this floor, and " seconds " will reduce the cost.

Walls.—Frame walls are the most common for the poultry house, although the use of the hollow tile wall is increasing. In the frame construction, a 2 by 4 or 2 by 6 sill is

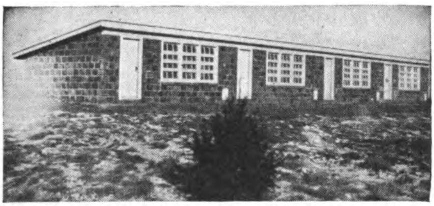


FIG. 122.—Shed type of poultry house.

bolted to the foundation. One half by 12-inch bolts are used, set 6 feet apart, and put in place when the foundation is poured. Two by 4-inch studding, set 2 feet apart on centers, a single 2 by 4 plate, and matched siding completes the wall construction. The wall height will depend on the type of house, and should be made just sufficient for headroom. From 5 to 7 feet is an average height.

The hollow tile affords a good wall, and one that is reasonably warm and tight. The blocks may be laid to form a 5 or an 8-inch wall, the latter being preferable. The blocks should be laid in a lime-tempered cement mortar, and the joints smoothed, or pointed. For corners and around openings brick may be used to fill out, or half tile may be secured.

Roof.—The roof rafters are usually 2 by 4-inch material, spaced on 2-foot centers. On longer spans than 14 feet, 2 by 6 should be used. The common wood shingle roof may be used. Tight sheathing and prepared roofing is now used to a large extent as a covering for the poultry house.

Windows.—Windows should be placed in the south wall of the poultry house to furnish abundant sunlight. One square foot of glass area should be provided for each 12 or 14 square feet of floor space. The location of the windows should be such that the January sun will shine on the floor, rather than on the roosts. Sunlight on the roosts in cold weather encour-

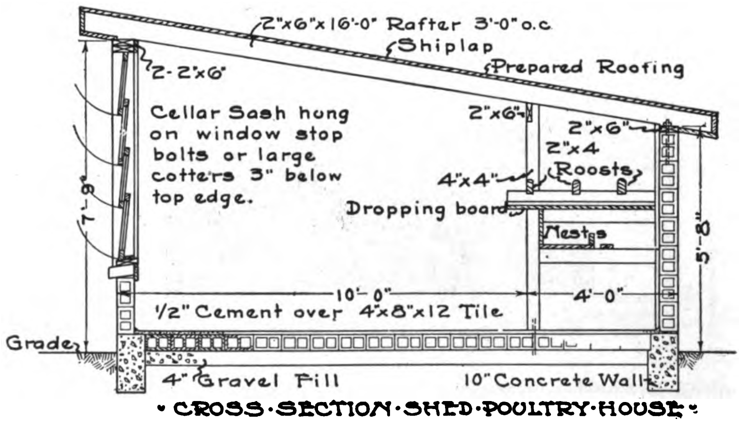


FIG. 123.—Cross-section shed type of poultry house.

ages the birds to remain on the roost. The discussion of sunlight in Chapter XIII should be noted. The windows are of the single-sash type, arranged to swing inward. The shed-roof type has the windows hinged at the top, and in the half-monitor house they are hinged at the bottom. A muslin screen is sometimes used in place of the glass sash. They should be hinged at the top, so they may be partially opened on clear days in winter. The openings in the south wall should be screened with a fine-mesh screen wire, and covered with a heavy-mesh hardware cloth, to keep the fowl inside the house, and prevent the entrance of small nocturnal animals.

Doors.—One or more entrance doors, at least 2 feet by 6 feet in size, should be provided in the ends of the house. The fowls require a small entrance opening about 12 by 15 inches in size for each unit. These entrances should be provided with a door that can be tightly closed.

Divisions.—The divisions which separate the sections of the poultry house may be tight partitions or they may be made of slats or poultry netting. Where more than three units are contained in the same house, it is advisable to make the partitions alternately of tight boarding and wire netting.

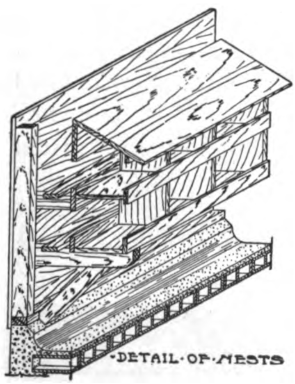


FIG. 124.—Detail of nests.

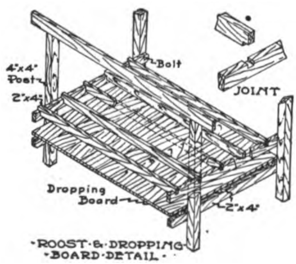


FIG. 125.—Detail of dropping board and roosts.

Ventilation.—The removal of moisture and provision for fresh air are fully as important in the poultry house as in the other livestock shelters. A complete system of ventilation with air flues and intakes is likely to make the building too cold. In the open-front house, the ventilation is provided through muslin screens. Inlets may be through windows in the other types of houses. Outlets for foul air are sometimes provided by making small doors over the wall plate, and between the rafters, which may be regulated according to the need. Drafts should not strike the fowls while they are on the roosts.

Poultry-house Equipment.—The necessary equipment for the poultry-house includes nests, roosts, dropping boards, and feeders. It is desirable in planning the house to arrange all of the equipment such as nests, roosts, and dropping boards near the rear of the house, leaving the front part for exercise and feeding.

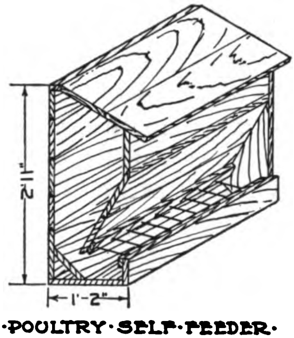


Fig. 126.—Detail of a self feeder.

Nests are placed under the dropping board, or along the end of the house opposite the entrance door. The usual size is 12 inches each way. The front of the nests should be closed by a hinged cover, with an entrance door for the birds at the rear. It is best to have runways up to the nests from the floor.

The roosts should be made of 2 by 4-inch material with the upper edge rounded, set in 2 by 4-inch beams, which are bolted to the studding at the rear wall is such a way that they can be raised. The roosts should be rigid, firm and all on the same level. About 14 inches should be allowed between roosts, and 8 to 10 inches of space per bird.

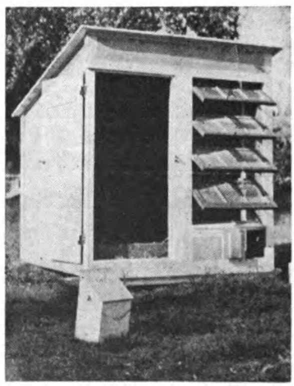


Fig. 127.—The colony type of poultry house.

Dropping boards are placed directly under the roosts, made of tight lumber, and nailed to the supports so the droppings can be raked off lengthwise of the boards.

The feeder should be used to feed dry feeds and mixed feed. It is a popular piece of equipment in poultry keeping.

Types of Poultry Houses.—The two types of houses in common use are the colony, or small house, and the community

or permanent house. The advantages and disadvantages of the community and the small colony houses are similar to the two general types of hog houses discussed elsewhere.

Colony Houses.—The small houses are usually built on sills, which serve as runners so the house can be moved about. The small colony house is almost the only type used for the town or city flock. The breeder with different breeds of pure-bred fowls will find the colony house suited to his needs.

Four by 4-inch wood sills are commonly used in the construction, together with 1-inch flooring, 2 by 4-inch framing, and tight boards for the covering. Prepared roofing

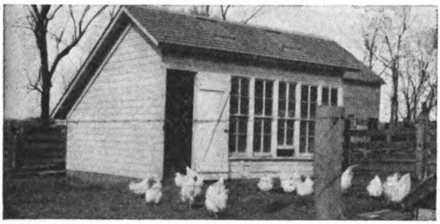


FIG. 128.—The combination type of poultry house.

may be placed over the sides and roof, for a warm, tight house.

The shed-roof house, 5 feet high at the rear and 7 feet high in front, with door and window in the south side, affords a good house for the small flock. A size of 6 by 8 feet will care for twelve to eighteen birds. The house may be built of cheap material to reduce the cost.

The gable-roof house, 6 by 8 feet in size with side walls 5 feet high, and door and window in the end, provides another good type of small house. The equipment is placed along the sides, leaving the center of the house for feeding. A small gable house can be made from two piano boxes.

Community Houses.—The community house is the more permanent type, two or more units being placed together under one roof. The type may be shed, gable, combination, or half-monitor roof.

Shed-roof House.—The usual width of the shed-roof house is 14 feet. The roof is a single slope, and the house faces the south. The north wall is made 5 feet high, and the front is about 8 feet high. The walls may be either of hollow tile or frame. This type house is frequently built with an open front. This is a popular, low-cost house.

Gable-roof House.—This is a two-slope roof house, with low walls, and rather a steep-pitch roof. The windows are placed in the gable ends.

Combination Roof.—This type of house has a short rafter

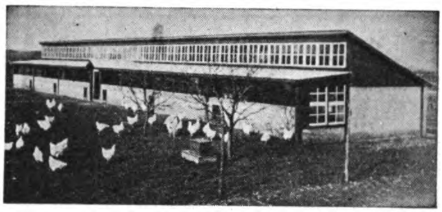


FIG. 129.—A large half monitor poultry house.

in the south slope, giving more headroom than the shed type. The south wall will accommodate full-size windows, and the doors are placed in the ends.

Half-monitor Roof House.—The "sawtooth" house is very popular in the Middle West. The front part provides a scratching shed 8 or more feet wide, and the usual width 10 feet is available for the equipment. The front wall is covered with screened openings, and adjustable windows are placed in the monitor.

CHAPTER XV

GRAIN-STORAGE BUILDINGS

GRAIN is the principal crop on a large number of farms, and in some sections it is the only money crop. The annual production of corn is about $2\frac{1}{2}$ billion bushels; of oats $1\frac{1}{2}$ billion bushels; and of wheat $2\frac{1}{2}$ billion bushels. The market value of the grains makes it essential that care be taken to preserve and market the crop in the best condition. Lack of housing facilities has resulted in losses due to weather conditions, rodents and fluctuating prices. A good grain storage makes it possible to hold the crop for favorable prices, and affords protection from the elements. It should provide for handling the crop with a minimum of hand labor.

Types of Grain Storage.—The three types of storage buildings for grain are the corn crib, granary, and combined crib and granary, or farm elevator.

If corn is the only product to be stored, the separate crib for ear corn, with possibly a tight bin for shelled corn is all that is required.

The separate granary is used for the small grains. The building is tightly constructed, with strong walls and heavy floors. All granary design should be figured for wheat storage, as it is the heaviest grain.

On the general farm there is usually corn, small grain, and some shelled corn to be housed. The combined grain-storage building is the best type of structure under these circumstances, and this discussion will consider the combined building.

Location.—Since the grain-storage building houses the grain used for the livestock, the building should be convenient to the feeding barn and hog house. There should be no fences

to interfere with wagons, nor gates to pass through with a basket. The building should be located so that a wagon may be driven through it, or pass alongside of the crib. It may be desirable to locate so that feed may be thrown direct onto the

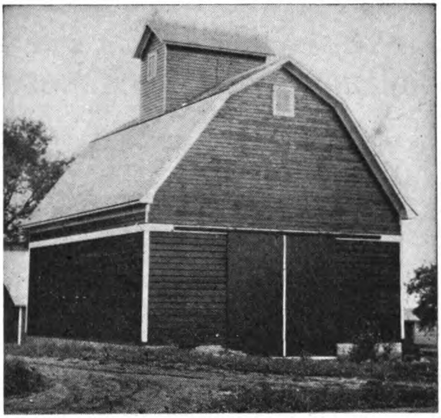


FIG. 130.—A double corn crib.

feeding floor. Provision should be made for operating shellers or elevators near the grain buildings.

Width.—The width of the corn crib is limited by the condition of the corn when cribbed. For most parts of the Corn Belt, the corn is cribbed before it is fully dry. To prevent spoiling and allow thorough drying out the width should be between 8 and 9 feet. Double cribs have a driveway 10 to 14 feet wide. Grain bins should not be more than 10 feet wide, for convenience. The double crib and granary will be from 26 to 30 feet wide.

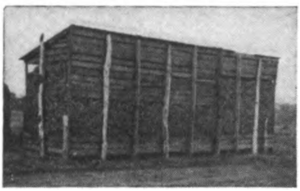


FIG. 131.—A temporary frame corn crib.

Length.—The length of the low crib, without power elevators, may depend on the amount of grain to be stored. With elevators, the grain storage

should not be more than 36 to 40 feet long, as the elevator will not carry the grain to the ends of the building in a greater length. For longer buildings it is necessary to use two elevators, or provide a portable elevator for several settings. A length of 36 feet will accommodate the grain on most farms.

Height.—Ten feet is about the maximum height of bin or crib for hand shoveling. With elevating machinery the height may be made as desired. Extremely high buildings waste corn by shattering as the building is filled. The best height is from 16 to 20 feet from foundation to eaves. Grain in overhead bins should not be deeper than about 12 feet.

Capacity.—To determine the size of building needed, it is

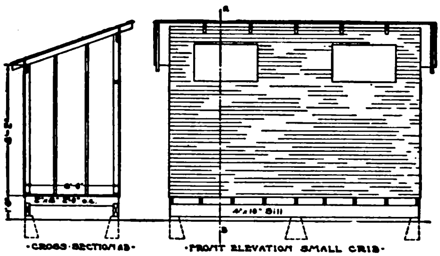


FIG. 132.—Single corn crib, section and elevation.

necessary to study yields, acreage, kind of grain, and type of farming. The total yield should be calculated, and the grain storage designed to hold the crop. One bushel of ear corn, husked, will occupy $2\frac{1}{2}$ cubic feet of space. One bushel of shelled corn requires $1\frac{1}{4}$ cubic feet. The small grains also take $1\frac{1}{4}$ cubic feet per bushel. The width of the building is fixed, within narrow limits. By selecting a convenient height or length, the other dimension can easily be determined.

Shape.—The most common shape for the combined crib and granary is the square or rectangular. This construction permits of a driveway, overhead bins, and convenience in handling the grain. Frame construction is easiest to handle in the rectangular building. Hollow tile and concrete, while

used in the square or rectangular buildings, are especially adapted to round buildings, and for this reason the round crib and granary have been advocated. The advantages are that the round building can be reinforced easily, affords a maximum of storage space, and is less expensive than the regular type of construction. Large grain interests use the masonry storage in the round form for their grain. The amount of grain on the average farm, however, is not sufficient to warrant the construction of the large bins.

Construction.—The following discussion refers to the

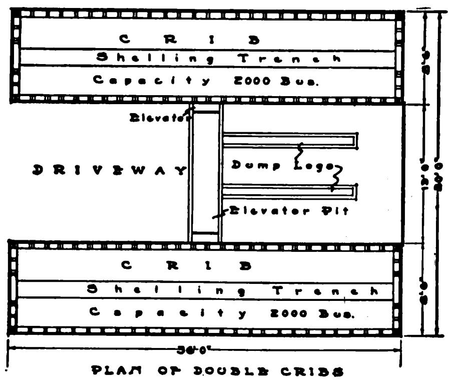


FIG. 133.—A plan of a double corn crib.

combined corn crib and granary. The construction of the single crib or the small grain bin is not of sufficient importance to warrant discussion. The small buildings are familiar in all sections of the country.

Foundations.—The weight of the corn crib and granary requires a firm foundation to prevent settling. The footing should extend below the frost line, on firm soil. The foundation under the crib wall should be 12 inches thick, and widened to 18 inches at the bottom, while that under the inside wall, which must carry the weight of the grain bins, should be made 14 inches thick, with a 20 or 24-inch footing. The foundation is made continuous around the building, and the

walls and floor brought 6 to 12 inches above the ground. A cinder or gravel fill under the floor and a tile drain around the foundation is sometimes necessary to avoid moisture.

Floors.—Both wood and masonry floors are used for grain storage. Wood is not rat proof, and decays quite rapidly under the usual conditions. Wood floors require heavy sills and supports to hold the weight of the grain.

Masonry materials are satisfactory for the corn or grain, when properly made. There should be no trouble due to dampness. Floors in the crib should be sloped to an outlet with a pitch of $\frac{1}{4}$ inch per foot, for drainage. There should be a fill of 6 to 12 inches of porous material under the masonry. The floor should be smooth, for easy shoveling.

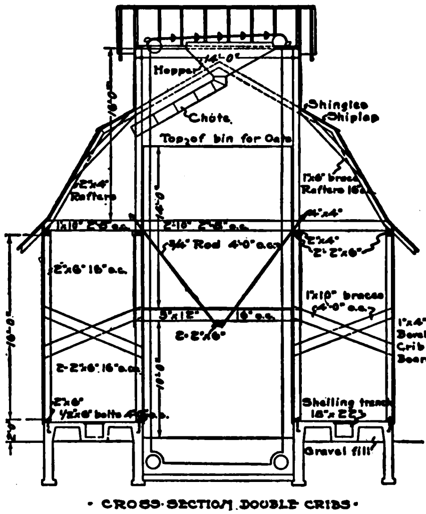


FIG. 134.—A cross-section of a double crib.

The masonry floor may be either of hollow tile or concrete. The concrete should be 4 to 5 inches thick, of a dense, jelly-like mixture, and troweled smooth. The tile floor is made from a layer of tile on a sand cushion, and covered with 2 inches of cement mortar. The driveway floor should

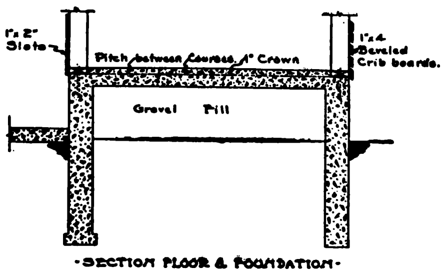


FIG. 135.—Details of foundation and floor for a corn crib.

be made of concrete in all cases. Bolts for the sill or studding sockets must be used with the tile or concrete floor.

Sloping Floors.—Some designers have advocated that crib and bin floors be made with a sloping floor, so the corn or grain will roll to the outlet, and save shoveling. The angle recommended is about 25°, as this is the angle at which the small grains will slide. This is not recommended here, for the following reasons. The cost of building a sloping floor is greater than for a level floor; small machines such as hand shellers could not be placed on the sloping floor; for small grain, all but a small portion of the grain will flow to an opening in the bottom of the bin when the floor is level; corn often becomes wedged so that there is no movement, and may form an almost vertical wall; there is some loss of storage space by the use of the sloping floor.

Crib Walls.—For frame construction, the studding should be 2 by 6-inch material, from the sill to the plate. The studding is spaced 16 inches to 2 feet on centers, and double studding set at intervals of about 6 feet. The framing must be firmly anchored at the bottom to prevent spreading. The common siding is crib or bevel siding, with the pieces set one-half inch apart; it is usually placed horizontally, although some prefer to use a diagonal siding. The inside walls of the crib are made in the same manner, except that it is necessary to set the studding 12 inches apart if overhead bins are used. The inside studding is carried to a plate under the bin joists, and the joists are placed directly over the ends of the studs. The bins are covered with shiplap or matched lumber.

Overhead Bins.—The joists of the bins over the drive should be designed for wheat, as it is the heaviest grain. In most cases the drive should not be more than 13 feet wide. The heaviest construction usually found is 3 by 14-inch joists spaced 1 foot apart on centers. This will support a depth of about 9½ feet of wheat. The joists are usually placed crosswise of the building, and serve to tie the structure together. An opening should be provided in the floor of the bin, through which most of the contents of the bin may be

drawn out without labor. The same objections to the sloping floor apply to the bin as to the corn crib. The bins should be made approximately square.

Ties and Braces.—The pressure of the grain in the crib and bins tends to spread the building. To prevent strain which might throw the building out of shape, cross-ties are essential. If the side walls are 8 feet or more high, one line of cross-ties should be placed at about the center height, and another row at the plate. The lower braces should be 1 by 12 inches, at every studding, and the braces at the plate should be at least 2 by 6-inch material, and spaced 2 feet apart. There should also be ties across the top of the grain bin.

Roof Construction.—The best type of roof for the combined crib and granary is the half-pitch gable roof. This roof affords headroom for the bins, and for the elevator. To accommodate the elevator head, a cupola is necessary at the ridge. The construction of this type of roof is discussed elsewhere.

Hollow-tile Construction.—There is an increasing use of hollow tile for grain-storage construction, and the material is satisfactory, and has several advantages as compared with frame construction. The tile is more fire-resisting and more permanent. Tile is readily adapted to round construction, which affords a maximum of storage space. The two types of tile buildings are the round and rectangular.

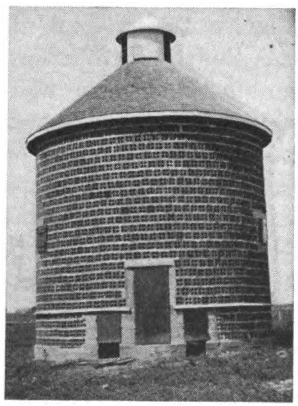


FIG. 136.—A round corn crib of hollow clay block.

The round crib and granary can be easily reinforced against the outward pressure of the grain. The disadvantage of round structures is that they are not so easily adapted to the storage of several kinds of grain. The economy of the round building lies in the possibility of in-

creasing the height to provide a large storage with one roof and foundation. Two walls are necessary in the round crib, the outer wall and an inner wall around a ventilating shaft. The ventilator is from 6 to 8 feet in diameter, the cribs are 8 to 9 feet across, making the total diameter 22 to 26 feet.

Foundation and footings are made of concrete. The walls are laid up with special crib tile, laid in cement mortar. It is necessary to reinforce the wall with reinforcing rods in the mortar joints, as in silo construction. Openings such as for driveway should have reinforced concrete frames, and the horizontal reinforcing is tied into the steel in the door frame. The roof construction may be of shingles and sheathing, or of roofing tiles.

The rectangular tile crib and granary provides a driveway and overhead bins. Inside elevators and grain-handling conveniences may be more easily installed than in the round building. The usual construction is to build the crib walls of tile to the plate, and use frame construction for the bins and roof frame. The problem is similar to any other tile building, except for the wall reinforcing. Horizontal steel is laid in the joints, at the rate of about 2 or 3 No. 3 wires to each joint. At intervals of from 5 to 7 feet there should be upright pilasters or wall columns to stiffen the wall. These pilasters should have at least four half-inch vertical reinforcing rods. The authors recommend that for tile grain buildings, the crib walls only be made of tile, and the upper part of the building be made of frame construction.

Recently there has been developed a type of tile building in which the gable ends, roof, and walls are all of tile. Only the overhead bins are of frame construction. This is an excellent type of building, but it involves many problems and as yet has not passed the experimental stage. Waterproofing, reinforcing, and high cost are the factors which tend to hold back the all-tile construction.

The crib blocks are special types, made with air spaces through the walls for ventilation. One type of block is cut at an angle, to prevent the entrance of moisture through

the wall, in case of heavy rains. Another block is cut square, with small openings through the wall. This latter type prevents the entrance of birds. The tile crib wall is made 8 inches thick.

Other Crib Materials.—Grain tanks have been made of both tile and concrete, and are successful. Sheet metal, wire fencing, and poles have all been used for less permanent types of storage. Concrete has been used in various forms for cribs, but as yet has found but limited use.

Special Features.—The value of the grain crop necessitates protection from rodents, fire, and moisture. The

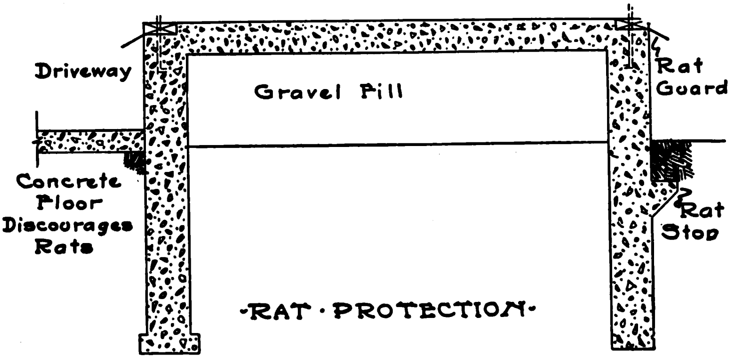


FIG. 137.—Details of rat guards for corn crib.

heavy labor required for hand shoveling makes it desirable that all possible conveniences and power appliances be used. These special features that should be included in the building are rat proofing, shelling trenches, gravity spouts, and elevating machinery. Proper construction will make the building fire resisting and moisture proof.

Ratproofing.—It is estimated that rats destroy over 200 million dollars' worth of food products every year, a large part of which loss occurs in the grain-storage buildings. If the foundation is carried down 2 feet below the grade line, it is unlikely that the rats will burrow beneath it. A tile or concrete floor will keep the rats from getting through. The other

possible entrance into the crib is through the side walls. To prevent this, a fine-mesh galvanized wire is placed against the studding, or inside the tile wall, and carried from the foundation to a height of about 2 or 2½ feet. At the top of the mesh, a strip of galvanized metal about 6 inches wide is placed around the wall, projecting outward and downward to form an apron. The rodents are unable to climb over this metal strip, and if doors are kept tight, they will be barred from the crib.

Shelling Trench.—To avoid the labor of shoveling the corn to the sheller conveyor or drag, the shelling trench is used in many cribs. The trench is simply a depression in the floor, about 18 inches wide and 18 inches deep. The trench is covered with short blocks of wood placed crosswise, before the crib is filled. At shelling time the conveyor is inserted in the trench, and the covering blocks removed as necessary. It is claimed that one man can regulate the flow of corn to the sheller, and save the labor of two or three men at shelling time. If the flow of corn is not carefully regulated, there is danger of choking the sheller drag. The trench may be used with either the sloping or level floor.

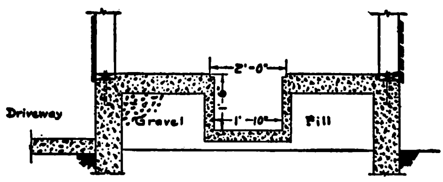


FIG. 138.—Detail of shelling trench.

Gravity Spouts.—With overhead bins it is possible to drive a wagon under the bin. If a spout is placed at the bottom of the bin, practically all of the grain can be drawn into the wagon without hand labor. The spout should be placed in the center of the bin if possible. A framed opening in the bin floor and a metal spout will be found satisfactory.

Elevating Machinery.—The best type of modern grain storage, with side walls up to 20 feet high, must have means of elevating the grain. Elevators which will unload a wagon load of corn or small grain without hand labor in five or six minutes are considered a necessity in many sections.

There are two types of elevators for the farm, known as the portable and the inside-cup elevator.

The portable elevator is best where there are several

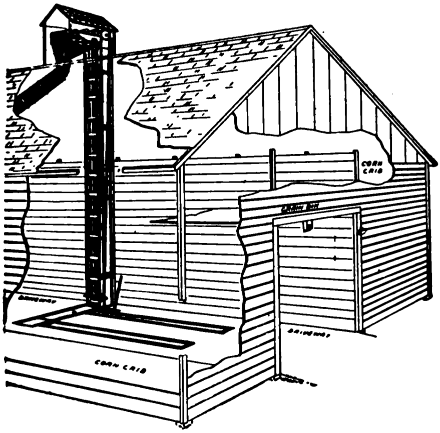


FIG. 139.—An elevator in place in crib.

different cribs or bins to fill, or where some grain is housed in the barn. This type can be moved about, and used in different locations, hence is favored by the tenant farmer. The disadvantages of the portable type are that the machine is

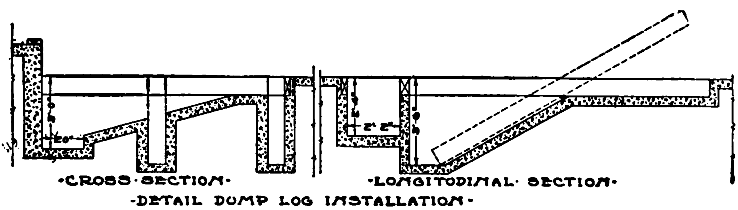


FIG. 140.—Detail of elevator pit and dump logs.

exposed to the weather, it is difficult to move about, and engine power is not so conveniently applied.

The stationary elevator is housed inside the elevator building, in a permanent location. The power may be con-

nected up by means of a line shaft, in permanent form. It is not exposed to the weather.

Elevators may be dumped by an overhead wagon jack or by dump logs. Both methods are used, and both are satisfactory. The dump logs must be installed at the time the floor is laid.

The hopper may be of the pit type, set below the floor, or a movable boot above the floor level. The pit may be made to accommodate a load of grain without operating the elevating machinery. The elevating sections consist of a box, or trough, through which the cups or fins carry the grain. The elevators are made in sections, and may be purchased for the height of the building.

The head of the elevator consists of a dumping device, hopper, and distributor spout. A cupola is required on the building to give sufficient headroom, so that the grain may be distributed to all parts of the building.

Handling the Grain.—In the well-equipped, combined corn crib and granary, practically all of the hand work has been eliminated. The elevator and dump will carry the corn from the wagon to the cribs, or small grain to the overhead bins. From the crib, the corn may be raked to the shelling trench and to the sheller. If desired the shelled corn may be re-elevated to the bins. From the bins the grain may be spouted to the wagons in the driveway. If a sheller and grinder is included in the equipment, it is possible to convey the corn from the bins to the machines by gravity, by a system of spouts.

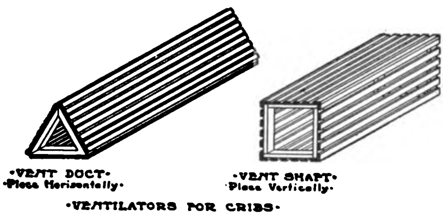


Fig. 141.—Ventilators for cribs.

Ventilators.—In the early corn-harvesting season the corn contains a high percentage of moisture. When this content is high, it is desirable to introduce air ducts and flues into the mass of the corn to hasten the curing process

and to prevent spoilage. Flues are made to set over the shelling trench and passages are made to extend across the crib

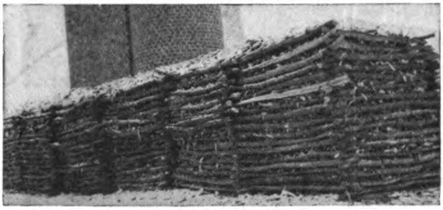


FIG. 142.—An old style rail corn crib.

to ventilate and dry the grain. Drain tile placed through the corn are convenient and efficient.

CHAPTER XVI

SILOS

The silo is one of the most important buildings on the live-stock farm for the preservation of green forage. It affords an economical storage, preserves the corn or forage crop in a succulent, palatable condition, and utilizes the crop completely as a feed. A silo must have several features, essential to secure good, sweet silage, regardless of the type or material used. Other features, not absolutely essential, add to the success and value of the silo.

Essential Features

Strong Walls.—The walls should be made sufficiently strong, by reinforcing, to resist the bursting pressure of the silage. The silage is packed firmly when stored, and as it settles, the outward pressure is still greater, and the wall must withstand severe strains.

Smooth Walls.—During settlement, the silage slides down the wall. Projections or rough joints hinder free and easy settlement, and air pockets are formed, which cause spoilage for some distance around the pocket. Smooth walls allow normal settlement.

Tight Walls.—For the preservation of silage, it is necessary that the walls retain the moisture inside the silo, and exclude the air. The silo walls must be air and water tight.

Desirable Features

Durability.—The silo should be so constructed and braced that it will be of service over a long period of years. A silo should return the first cost in two or three years, but

the greater the durability, the more profitable the investment.

Low Repair Cost.—Constant attention and repairs to any farm building lowers the profit from the building. The silo should be of such construction that it requires little attention.

Good Location.—The silo should be accessible for filling, both for the wagons and filler. For the dairy barn, the silo should be near one end of the feed alley. For beef cattle, it should be near the yards, and arranged so full loads of silage may be taken directly from the chute at one time.

Wind Resistance.—Shelter and bracing, together with substantial construction, will tend to prevent the silo from blowing down in high winds.

Frost Resistance.—In severe weather the silage will freeze in any silo. Double walls, dead-air spaces, or insulating material will retard freezing, and will also retard subsequent thawing. If the silo is sheltered from the winter winds, and set where direct sunlight will strike it, the freezing can be partly prevented. Silage is not damaged materially by freezing, if it is thawed before feeding, and fed immediately after it is thawed. If the silage is removed around the outer edge first, and the top of the silage kept in the shape of a low hay shock, much of the trouble is avoided. The center of the silage should not be removed and the sides left, simply because they are frozen.

Simplicity of Construction.—A silo easily constructed, without highly skilled labor, is of advantage to the farmer. A short period of erection is usually desired.

Appearance.—The silo is a prominent building in the group, and a good appearance is necessary for making the farmstead attractive.

Cost.—The upkeep cost, length of life, and capacity are as important as the first cost, and the more expensive silo may be the best investment when figured over a term of years.

Size and Capacity

Amounts Fed.—Experience determines the exact amount of silage to be fed to farm animals. The following table indicates the average amounts usually recommended:

	Pounds per Day
Dairy cows	35 to 40
Stock cattle	20
Fattening cattle	25
Calves	12
Sheep	3

If the number of stock is known, and the length of the feeding season determined, the number of tons needed can be found, and the size of the silo made accordingly.

Rate of Feeding.—To keep the silage sweet, it is necessary that some silage be taken off the top each day. The rate of removal will depend on the weather, but from $1\frac{1}{2}$ to 2 inches should be fed off each day. The diameter of the silo will vary with the number of head of stock to be supplied. The following table, from Nebraska bulletin 138, shows the number of dairy cows supplied by silos of different diameters:

Diameter, Feet	No. of Head
10	13
12	19
14	26
16	34
18	42

Capacity.—The capacity of round silos, in tons, based on the tables by King, of the Wisconsin Station, are given in the following table:

Diameter, Feet	Height in Feet						
	28	30	32	34	36′	38	40
10	42	47	51	56	61	65	70
12	61	67	74	80	87	94	101
14	83	91	100	109	118	128	138
16	108	119	131	143	155	167	180
18		151	166	181	196	212	229

Weight at Different Depths.—The weight of the silage is greater in a high silo than in a low one, as the pressure compacts it to a greater weight in the lower part. As a result, the high silo is the more economical, and the increase of capacity should usually be secured by increasing the height, rather than the diameter, in a new silo. The following table, based on Iowa, Nebraska, and Wisconsin figures, show the weight at different depths:

Depth of Silage from Top Feet	Average Weight, per cu.ft.
4	21.25
8	24.50
12	27.50
16	30.50
20	33.33
24	36.
28	38.33
32	40.62
36	42.75
40	45.
44	47.
48	49.

To determine the amount of silage remaining in a silo partially emptied, it is necessary to multiply the cubic space of the total fill of silage by the mean weight for the depth

considered, and subtract from this figure the mean weight of the amount used. The remainder should indicate closely the amount remaining.

Silo Construction

Foundation.—The solid concrete foundation is the most common for silos. It should be made 10 inches wide, and

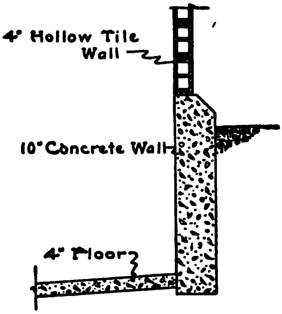


Fig. 143.

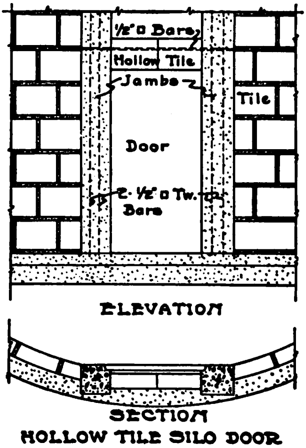


Fig. 144.—Detail of concrete door frame for hollow tile silo.

extend from below the frost line to a point several inches above grade. A 1:2:4 wet mixture of concrete should be used. The trench should be laid out to the diameter of the silo. The part above ground is poured in forms, made of thin boards, and bent to shape. The top of the wall must be smooth and level.

The earth inside the forms may be excavated, after the concrete has hardened, to secure additional space. The foundation should be 3½ to 4 feet deep, and most builders prefer to excavate to the depth of the foundation. This space is secured at slight cost and it is not difficult to lift the silage a few feet. The inside of the foundation wall should be plastered with a cement plaster, to make a smooth wall.

Walls.—Silos are usually designated, as to type, by the material used in the wall construction. The general classes of silos are wood, masonry, and metal, the first two comprising most of the silos in common use.

Doors.—Doors for the silo may be of the individual or continuous type. The individual doors are spaced at intervals of about 4 feet on centers, each door set in a separate frame. With this door it is necessary to lift the silage several feet, until the next door is reached. The continuous door has sides, or jambs of masonry or steel, and cross-ties prevent the jambs from spreading, the ties serving as a ladder in many silos.

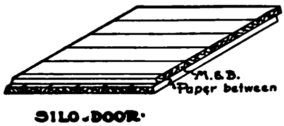


Fig. 145.—Detail of door to fit frame shown in Fig. 144.

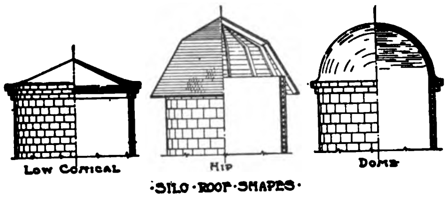


Fig. 146.

The continuous door is used almost entirely at present, and is made in sections convenient to handle.

The doors are of two thicknesses of wood, and are made to fit into a rebate, or ledge, in the jambs. To make a tight joint it is necessary to have a felt gasket or some plastic material between the door and the jamb. Clay, mixed to a putty consistency, or a linseed meal paste may be used.

Chute.—Chutes are used to cover the doors, and afford a means of throwing down silage without trouble from the wind. Wood chutes are easy to make and cost less than the other types. Metal and concrete are used in some cases.

Roof.—In many localities the silo is not provided with a roof. The purpose of the roof is to afford protection from rain and from freezing. The roof will improve the appearance of the silo, but if the protection is not needed, the roof may be omitted.

The two roof types commonly found are the low conical roof and the round gambrel roof, which is sometimes locally known as the "hip" roof. The conical roof may be made of wood, metal, or concrete. The wood roof is of ordinary frame construction, using 2 by 4 rafters, sheathing, and shingles, or prepared roofing. The metal roof is a commercial product, and may be purchased. If the metal roof is not anchored very firmly, it is likely to blow off. Concrete is a desirable material for the roof; it must be reinforced, and supported until the concrete has set. The low roof makes it impossible to fill the silo full to the top, and after the silage has settled there will be some waste space. Tramping is not easily accomplished near the top.

In the gambrel roof the silage can be filled to the top of the wall, or slightly higher, and thus increase the capacity. The gambrel roof is made of frame construction, but is more difficult to make, and costs about twice as much as the low roof.

Reinforcement.—The outward pressure tending to burst the silo depends upon the depth of the silage. Professor King of Wisconsin determined that the pressure increased 11 pounds per foot for each foot of depth—thus at the bottom of a 32-foot silo the pressure is 352 pounds per square foot. Steel, in the form of rods or bars, is the common reinforcing material. In the stave silo the steel may be in the form of hoops. In most of the masonry silos, the steel is bedded in the wall material or in the mortar joints. The steel should be carefully figured to withstand any strains likely to be placed upon it. A water tank requires five or six times as much steel as a silo of the same height.

The amount of steel varies from the bottom to the top, requiring less steel to care for the pressure near the top of the silo. The following formula, adapted from a tank formula by Taylor and Thompson, is used to determine the amount of steel for the silo:

$$A_b = \frac{11HD}{2f_s},$$

where H is height of silo in feet above section considered;
D is diameter of silo in feet;
A_b is area of steel in square inches, per foot of height at section considered;
f_s is the allowable stress, per square inch of steel—12,000 to 16,000 is used;
11 is a factor depending upon the silage pressure.

Example.—How much horizontal reinforcing is required for each 8-inch joint, for a silo 14 feet in diameter, and 32 feet high? Steel required for bottom joints.

$$A_b=\frac{11\times 32\times 14}{2\times 16{,}000}=.098 \text{ square inch per foot of height.}$$

The joints are 8 inches or $\frac{2}{3}$ feet apart. $\frac{2}{3}$ of $.098=.065$ square inch. This would be secured in three No. 3 wires, each with an area of $\frac{1}{20}$ square inch

Types of Silos

Each of the general divisions of wood and masonry silos have several forms that are successful and widely used, each of which types will be discussed. The metal silo is not widely used, and the cost is higher than for the other types. Wood is the most common and best known type, and the masonry silos are being used in increasing numbers.

Wood Silos

Wood-stave Silo.—This is the most common type of wood silo. It is one of the oldest forms, and is very efficient. When properly braced and cared for the stave silo should last from ten to twenty years. It is now being replaced to some extent by the more permanent masonry types. The staves are made from a high-grade of cypress, white pine, redwood, fir, or hemlock. The size of the stave is about 2 by 6 inches, and each one is beveled to fit the curve of the silo, and tongued and grooved to give a tight fit. The walls are

tight, smooth, and when properly hooped, are strong. Bracing by means of stay wires is necessary to prevent the silo from blowing down.

The stave silo requires some attention to keep the hoops tightened in the summer. A barrel left exposed to the sun and rain for a season becomes loose, and the staves may fall down. The silo is comparable to a barrel with the head removed, and care is necessary to keep it from disintegration. The hoops should be tightened once a week during

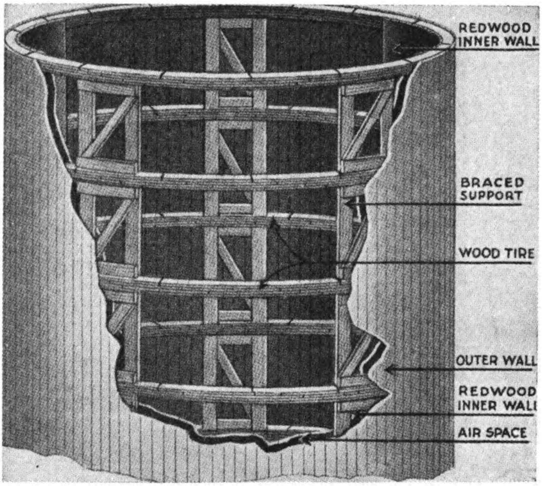


FIG. 147.—Showing construction of the wood hoop silo.

the summer when the silo is empty; when it is filled, the hoops should be loosened, as the moist silage swells the staves, and the hoops shrink with the coming of cold weather. The hoops should be regulated so the staves are firm at all times, but not tight enough to crush the wood.

Panel Silo.—The panel silo is known by several trade names. It consists of ribs or uprights set 20 to 24 inches apart, and matched boards set horizontally between the ribs. Steel hoops are placed around the silo and hold the boards in

place. This silo is not round, but is in the form of a many-sided polygon, each panel being straight. The advantage of this type is that short pieces of material are used in the construction.

Triple-wall Silo.—This silo is the ordinary stave type, with a layer of insulating material over the staves, and a thin drop

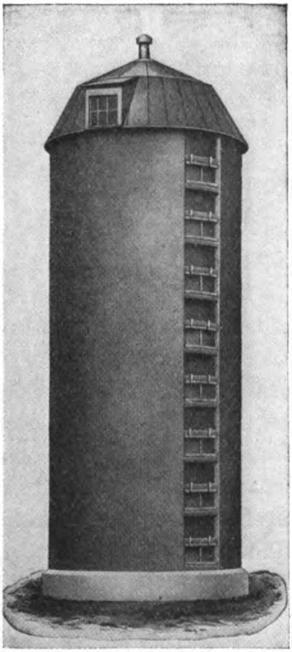


FIG. 148.—The wood-hoop silo.

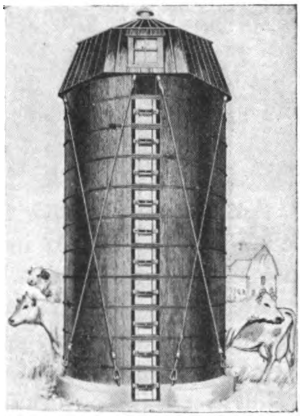


FIG. 149.—A creosoted wood-stave silo.

siding bent to form, and nailed over the outside. The siding serves as hooping, and protects the staves. Old stave silos may be covered in this manner, and their usefulness is prolonged.

Wood-hoop Silo.—The wood-hoop silo is made by building large wooden hoops, from four or five thicknesses of thin wood, bent to the circle. They are spaced twenty-four to thirty

inches apart, and matched flooring is placed inside and outside the hoops. This affords a double wall with dead air space.

Creosoted-stave Silo.—The stave-silo material is sometimes treated with creosote preservative to lengthen the life of the wood. The three methods of creosoting are painting, dipping, and immersing under pressure. The latter method is preferable, as the creosote is forced into the pores of the wood. The use of the preservative will make the cheaper woods last longer, but the material should be of a good grade.

There are some other types of silos on the market, but for the most part they are adaptations of those described.

Masonry Silos

The masonry silos include brick, hollow tile, and concrete. The concrete silos may be concrete block, cement staves, or monolithic concrete.

Brick Silos.—This type of silo has been in use for a number of years. The brick, if of a good grade, makes a nice appearing silo. The chief difficulty is to secure proper horizontal reinforcing in a 4-inch wall, with a narrow mortar joint. A flat bar, crimped on the inner edge, to form a curve, is now used. The bar is about $\frac{1}{8}$ by $1\frac{1}{2}$ inches in size, and bonds well into the joint The wall should be laid up carefully so it is not porous. The interior is plastered with a cement mortar, to insure a smooth, tight wall. Paving brick are used in the construction of the brick silo.

Hollow-tile Silos.—The use of hollow tile or clay blocks for silos was developed by the Iowa Experiment Station and the type is usually known as the Iowa silo. The first one was erected in 1908, and is still in use.

The blocks used are 4 to 6 inches thick, and the 4-inch block is preferred by some masons, as it is easier to handle. One or more air spaces are formed in the block. Some blocks have special grooves to receive the reinforcing. The silo blocks are curved to the form of the silo wall, and can be secured from widely distributed factories.

Experienced labor should be secured to lay up the blocks, as it requires care and experience to get a good, tight wall.

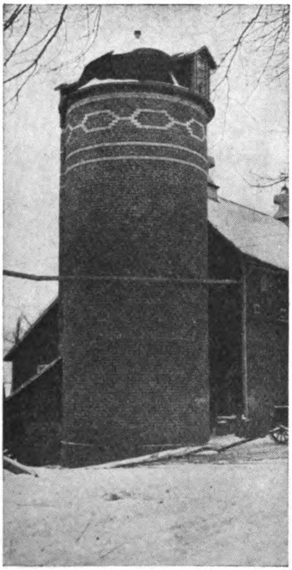


FIG. 150.—A brick silo.

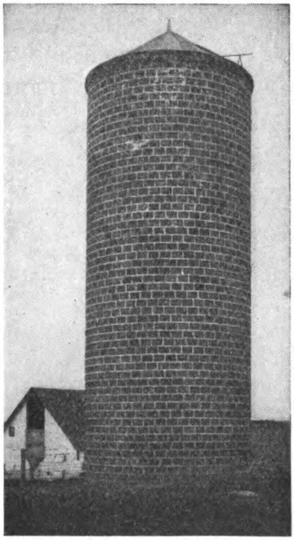


FIG. 151.—The Iowa or hollow clay block silo.

Men specialized in the erection of tile silos usually do better work than masons not familiar with tile construction.

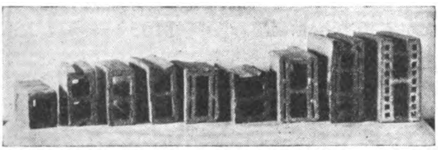


FIG. 152.—Shapes of hollow blocks used in silo construction.

The reinforcing consists of heavy steel wire embedded in the mortar joints. Reinforced concrete jambs are used, and these are tied across at intervals, to prevent spreading. The

continuous door is used. The mortar joints should be pointed both on the inside and outside wall, as a precaution against leakage. Since the vertical joints are the weakest part of a tile silo, care must be taken to fill the joint and secure a good bond. As an additional safeguard the silo should be given a wash of pure cement and water inside to fill the pores.

The tile silo costs more than that of wood, but is strong,

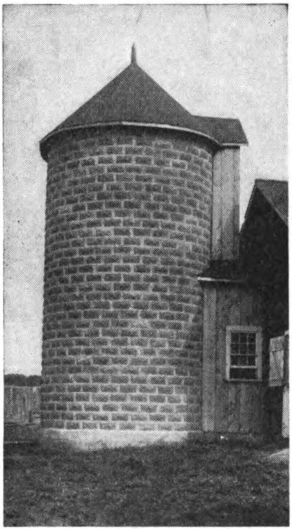


FIG. 153.—A concrete-block silo.

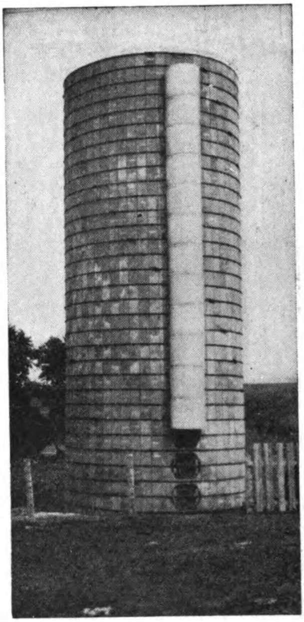


FIG. 154.—A concrete-stave silo.

permanent, attractive, and contains one or more dead air spaces. Either the conical or gambrel roof may be used.

Concrete-block Silo.—There are several patented blocks used for silo construction. Some are curved, and have imitation rock faces. Others are made in various forms, and named from the form. Reinforcing is either embedded in the block or placed in the mortar joint. Stucco is sometimes applied to the surface, for appearance, and to fill up the pores. A pure

cement wash is applied to the interior. Some contractors use alum, or commercial waterproofing compounds in this wash.

Cement-stave Silos.—The Playford cement stave was originally used in a Michigan silo in 1904. In the past few years, this and other patented staves have been widely used.

The Playford block is book-shaped, $2\frac{1}{2}$ inches thick, 10 inches wide, and 28 inches long. The Interlocking patent has an interlocking end joint. The Caldwell block has an end step joint and reinforcing in the block. The Perfection block has a hollow side joint which is filled with mortar.

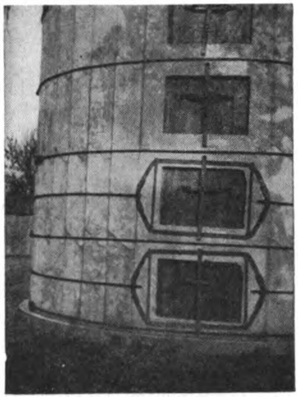


Fig. 155.—One type of door used with concrete-stave construction.

The staves are set with the end joints broken, or interlocked, and the silo staves bound with steel hoops, similar to the wood staves. In medium or large silos, it is advisable to place a hoop at the middle and end of the stave, or about 15 inches apart. This requires special door spreaders for the hoops. The hoops are $\frac{9}{16}$ to $\frac{5}{8}$ inch in diameter, and threaded at the ends. Since steel and concrete expand and contract at the same rate, the hoops do not need tightening in the summer. The staves are made in a factory, and shipped to the job. Only experienced help should be used, or leaning and twisted silos may result.

Fig. 156.

After the silo is erected, the hoops are tightened, and the interior given a cement wash. The cost of the stave silo is about the same as for a good wood structure.

Monolithic Concrete Silos.—Solid concrete makes an excellent silo. Standard forms are used, and the entire work is

done on the building site. The time required for erection is longer than for the other types. The cost can be materially reduced if farm help can be used for most of the work. If sand and gravel are close at hand, the concrete silo is not expensive. The walls are usually built of a rich mixture of concrete, in the proportion of 1: 2: 4. It should be well spaded

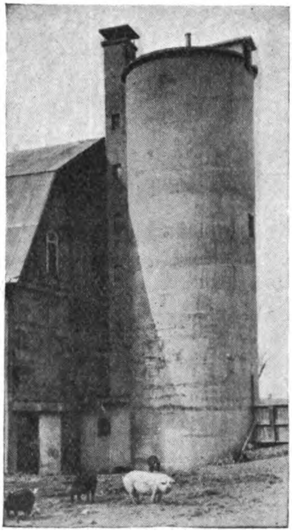


FIG. 157.—A monolithic concrete silo.

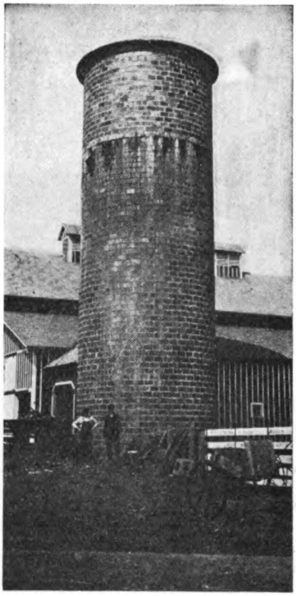


FIG. 158.—A water storage tank on hollow-block silo.

to give a smooth wall, and prevent the aggregates from separating. The reinforcing is embedded in the wall. The only upkeep required for this silo is an occasional washing on the inside with a cement wash.

Pit Silos.—In sections where the soil is dry, and will not cave readily, the pit silo is possible. A circular hole is dug, and the hole plastered or bricked up, similar to a cistern. The pit silo is cheap, easily made, and satisfactory. The filling

requires little power, but there is considerable power necessary to lift the silage from the pit.

Tank on Silo.—The silo tower affords a splendid elevation for the water-storage tank. The tank is frequently placed on the masonry, hollow-block and concrete silo. Care should be taken in thoroughly waterproofing the tank wall, which is constructed of hollow tile or brick. The supply pipe should be well protected against freezing. When these two features are considered and guarded against this tank cannot be equaled for cheapness of tower, water pressure, and service. Either a beam-supported concrete floor slab or a low conical-shaped reinforced floor may be used for bottom of tank. A low conical-shaped roof is usually placed over the tank with scuttle for access to the interior.

CHAPTER XVII

IMPLEMENT AND MACHINE SHELTERS

FARM machines have always suffered from lack of care and housing. When farm tools were simple in construction and low in cost the loss was not serious, a small space in the barn or crib being sufficient to house the more important

FIG. 159.—Farm machinery exposed to the weather.

implements. At the present time farm machines are expensive. The tractor, car, motor truck, and binder, as well as the more common machines, lose value rapidly when constantly exposed to the weather. Official estimates place the annual loss, in depreciation due to lack of shelter, at more than 100 million dollars.

The development of farm management ideas in farming has led to a realization of the losses in farm machinery, and the value of the shelter is now understood. Some arguments

have been brought forward to the effect that if machines were properly greased, and painted every year, the loss due to exposure would not be serious. The general opinion of practical men is that housing will increase the life of farm machines by five years or more, a saving which would pay for the cost of the shelter in a few years. Sheltered machinery is better in appearance, longer lived, and more efficient than neglected equipment.

Essentials of Machine Shelters.—The necessary qualifications of a machine shed are that it give protection, afford convenience in storage, and provide plenty of space.

Protection.—The principal function of the shelter is the protection of the implements from the elements and from animals. Exposure to the weather causes rust of metal and decay of wood. Tractor parts, plowshares, binder knotters and other complicated parts will not operate properly unless protected from the effects of rain, snow, and dust. Small animals should be kept from the machines, because of the danger to the stock as well as harm to the machinery. Farm poultry, especially, should not be allowed to make a roosting place of the machines. During the winter season the machines should be repaired and adjusted, and protection to the worker at such times is important.

To meet these requirements of protection, the machine shelter should be tightly inclosed on all sides and have a tight roof. Continuous doors along one side are much preferable to the open shed. Windows at intervals will supply better light by which to work. A concrete or plank floor is desirable as an added protection.

Convenience.—Correct width, proper location of doors, and large openings will add to the convenience of the machinery building. The location should be such that wagons and spreaders may be driven into the shelter, and not run in by hand each time. If the less-used machines are placed at the rear of the building, the regularly used equipment will be convenient to the doors. The grouping of machinery according to seasonal use is recommended.

Space.—Sufficient space should be provided for all of the machinery likely to be used on the farm. An inventory of machines should be taken, and measurements made to determine the size of the building. Some machines may be taken apart, or the tongues removed in order to save space. The table will show the average amount of floor space required for the commonly used machinery. The figures for height are unimportant, except for the hay loader.

The following figures are for average machines with the tongue removed:

Implement	Width	Length
Walking plow	2′	7′
Gang plow	5′	9′
Engine plow, 4 gang	7′ 6″	12′
Harrow, per section	1′ 6″	5′
Disk harrow	8′	4′
Land roller	8′	3′
Grain drill, 8 hoe	5′	10′ 6″
Corn planter	6′	5′
1-row cultivator	5′	7′
2-row cultivator	7′ 6″	7′
Sulky rake	5′	11′
Side delivery rake	10′ 6″	12′
Sweep rake	10′	12′
Hay loader	9′	10′ 6″ 10′ high
Mower	6′	6′
Binder, 7′ cut	9′	14′
Silage cutter	7′	12′
26-inch thresher	8′	26′
Wagon	7′	14′
Buggy	6′	9′
Tractor	7′	12′
Automobile	6′	12′

Location.—The machinery building should be easily accessible from the fields and horse barn. A location on the lane or drive to the fields is desirable, and one closer to the house than that of the barns is not objectionable. The

shelter may also serve as a windbreak for the stock barns, and should be on a convenient driveway in order that the wagon and spreader may be housed each day.

Size.—The width of the building depends upon the amount

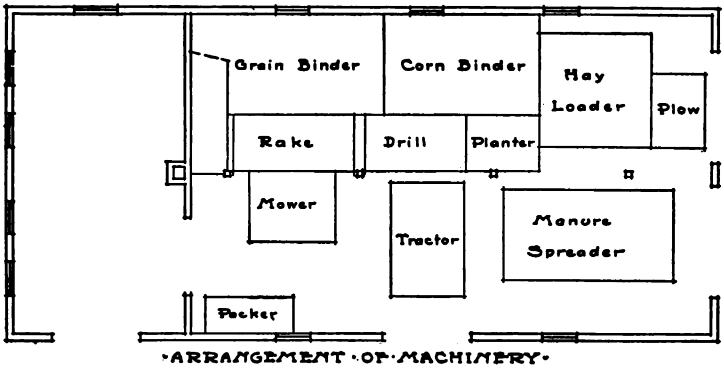


FIG. 160.—Floor plan of implement shed showing spacing for machines.

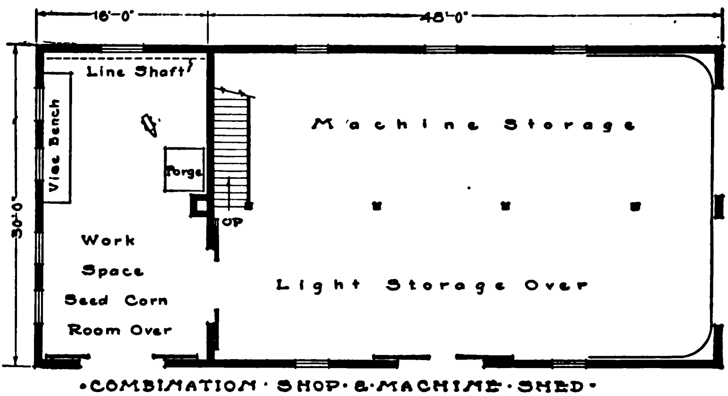


FIG. 161.—Floor plan of a combination shop and machine shed.

of machinery to be stored and economical considerations. For small amounts of machinery a width of 18 feet is suitable. A 26-foot building will shelter a wagon, including the tongue, and will shelter a large amount of machinery per foot of

length. Buildings wider than this are more difficult to frame, and storage is not so convenient. Any even width between 18 and 30 feet will be found satisfactory.

The length will be made to fit the amount of equipment used on the farm, and should be made in units of 10 or 12 feet for best results in storing. Ten feet is the maximum height necessary to accommodate the usual farm machines.

Arrangement.—The space arrangement should be made with the idea of storing the machinery by groups according to the seasonal use in the field. The groups will usually be tillage tools, seeding and cultivating machinery, harvesting and haying machinery, and power equipment. Each group of machines is housed in a section of the building, and stored in such a way that it can be removed in the order of its use. Tools used only once in the year should be placed at the rear of the building, while carriages or other frequently used equipment should be placed near the door.

For storing wagons, spreaders, and tractors, it is well to have a door at each side of the building in order that these machines may be driven in and out of the shelter without hand work or backing. For wagon and manure spreader a closed shelter is not essential, and this part may be simply a shed roof, without doors. For the rest of the building continuous doors on a parallel track installation will give the best results.

Types of Shelters.—The machine shelter need not be expensive if it affords the essentials of protection, convenience, and space. Compared with the barns, the machinery building will be low in cost, for the essentials of warmth, drainage, sanitation, etc., are not so important. Barn space is too expensive for machine housing.

The open-shed house, if used, affords a cheap protection from rain and snow, but it is not so desirable as the closed building. The shed is opened to the east for best results. The closed building with doors along one side affords full protection, and is recommended as the best. Two-story buildings have loft space for small machines and miscellaneous articles.

Frame construction is most commonly used, and is satisfactory. Hollow tile or cement products may be used in the wall construction as in any other building.

The roof shape is usually of the shed, gable, gambrel or "combination" type. The combination roof has two unequal

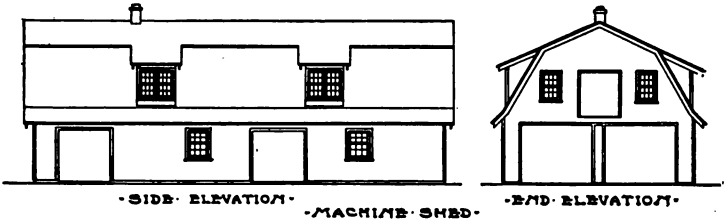


FIG. 162.—A two-story implement shed.

slopes, with the object of securing greater headroom with the least material.

Construction.—The foundation of the machinery building need extend only about 18 inches below the grade line. The width is made 8 inches, and the footing is widened to afford a bearing surface. The masonry is carried to a height of 12 inches above the ground line.

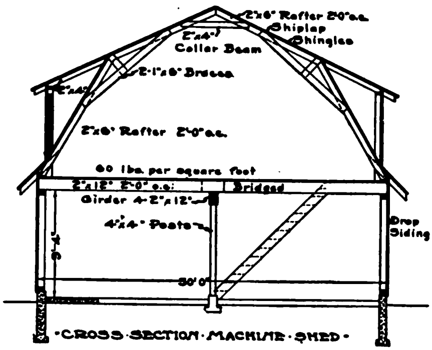


FIG. 163.—Cross-section of the shed shown in Fig. 162.

The frame walls are made of 1-inch siding or boarding on 2 by 6 studding spaced 2 feet apart, or 4 by 6 uprights spaced 6 feet apart, with nailing strips and braces between. The walls should be carried to a height of 10 feet to the plate. The roof frame must be cross braced and trussed for strength. The kind of framing will depend on the width.

The floor may be of plank or concrete. To reduce the cost,

cinders or gravel may be used in place of the more substantial flooring.

Doors should be strongly built, and set on a good type of track and rollers. For the continuous door it is possible to secure a parallel track outfit which makes it possible to open up any part of the building.

Garage

Every modern farm has need of a garage for at least one or two cars. A separate building for power equipment is desirable, as no machine using gasoline or kerosene should

Fig. 164.—A frame garage.

be housed in the barn, corn crib, to other building where the fire risk is great.

A garage building provides a shelter for the car, reduces the fire risk in other buildings, affords storage for oils, fuel, and tools, and furnishes working space for handling repairs. The garage should be of good appearance, fireproof, light, clean, and reasonably warm.

Size.—The actual room required for the car varies from 6 by 12 feet to 7 by 16 feet. To provide working space around the machine, and room for a work bench and other conveniences the garage should be 12 by 16 feet or more. For two cars the minimum size should be 18 feet each way. Doors

should be 8 to 9 feet wide and 8 feet high. The height of the building to the plate need not be more than $8\frac{1}{2}$ feet. Tight-fitting doors on substantial track are essential. There are several patented door outfits on the market that are satisfactory. Two or more windows should be provided to allow light for working with the car.

Oils and Fuel.—Supplies for the car and tractor are usually purchased in quantities for farm use. Oils and grease do not require much room and may be left near the work-bench, if kept well covered. The best method of handling gasoline is by means of an underground tank, several feet away from the building, connected by a line of pipe and gasoline

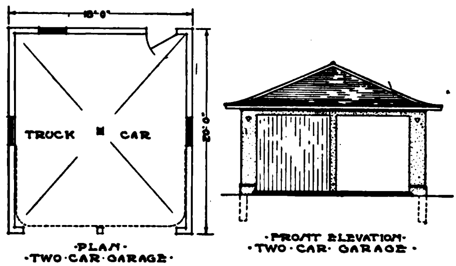


Fig. 165.—Plan and elevation of two-car garage.

pump. Fuel oils should at least be kept tightly covered in metal containers, and carefully handled. No filling should should ever be done at night with open-flame lights. Matches and cigars will prove very dangerous around the fuels in the garage. Oily waste and rags should be kept in metal cans, and destroyed at intervals.

Appearance.—The same rules of appearance apply to the garage as to any other building on the farm. It will often be noted that, for some reason, the garage either on the farm or in town seems to be built without any regard to appearance.

Fireproofness.—The garage houses valuable machines, and the fire risk is perhaps greater than in any other building on the farm. Since the garage is a small building the cost of fire-resisting materials is small, and masonry construction is a

good investment. Most of the danger from fire comes from within, and good results can be secured by concrete floor, masonry walls, and frame roof construction.

Light and Cleanliness.—These elements should be secured both for convenience and safety. Windows at the rear of the structure and one on each side will afford sufficient natural light. Electric lights should furnish the only source of night lighting on account of the danger from open flames. The building should be washed frequently and all accumulation of litter removed promptly.

Construction.—The foundation for the garage should extend about 12 inches below the grade and for frame walls the foundation wall is carried 12 inches above grade. A 4-inch, one-course cement floor sloped to a drain is satisfactory. Frame walls are made of 2 by 4-inch studding with 1-inch matched siding. Studding are doubled at the corners and diagonal braces should be used for strengthening. The roof is usually constructed in either the gable or hip style with 2 by 4-inch rafters and 1-inch cross ties.

Hollow tile, brick, or concrete are favored for garage construction on account of their fire-resisting qualities.

Tractor Shelters

The increasing use of the farm tractor brings the problem of a tractor shelter to many farms. In too many cases the problem has been solved by leaving the tractor in the open from one season to the next; but it is an expensive machine, costing as much or more than the motor car, and since its work is of a productive nature and its parts are more exposed than those of the motor car, it requires shelter and care equivalent to that given the motor car or truck.

The space needed for the tractor will be about 6 by 12 feet, with additional space around the machine for convenience in working. So far as the requirements of a tractor shelter are concerned, they are similar in every respect to those of the garage, in which the car and truck are housed. The tractor

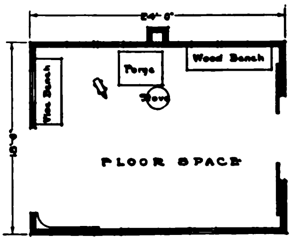
may be sheltered in a separate building, or with the car or truck in a double garage.

FARM SHOP

Modern farming makes extensive use of power equipment and complex machines. Efficiency demands that all of the equipment be kept in working order. The farm shop is valuable in the busy season for emergency repairs, and during the winter season for thorough overhauling of all of the farm machinery. In many localities the village blacksmith is gone, and it is becoming difficult to secure quick repairs.

Equipment.—It is not the purpose of this text to detail the equipment needed in the farm shop. Usually the equipment will be built up gradually from a small beginning. It is best in all cases to buy a few good tools rather than complete sets of tools of questionable quality. The farm shop should have a steel square, rules, saws, hammers, chisels, planes, draw knife, ratchet brace, and boring tools. A forge and anvil, with blacksmithing tools, is desirable on farms with considerable mechanical equipment. A gasoline engine or electric motor will operate the power tools in the well-equipped shop.

Size.—The dimensions of the farm shop should be made sufficient to accommodate benches for woodwork and forge, cabinets for tools, and at least one large machine such as a binder or tractor. A size of 20 by 20 feet will be the best. To accommodate large machines brought in for repair work there should be at least one 8 or 9-foot door, and preferably a large door in each end of the shop.



·FARM·SHOP·PLAN·

FIG. 166.

Plan.—In planning the shop the center space should be kept clear of equipment. The forge and carpentry equipment should be separated as much as possible to reduce fire risk. The forge and iron bench will be placed at the side near

one corner. The line shaft and power tools may be along the same side. The carpenter bench should be placed on the opposite side. All arrangements should be made to throw light on the work to be done.

Construction.—The machine shop should have a concrete floor, and either masonry or frame construction is satisfactory. The framing and construction follows the same lines as the garage and tractor shelter, or other small buildings.

Combination Garage Building.—The statement was made above that the tractor shelter, garage, and tool shop all embodied the same features of plan, essentials, and construction. The same tools, oils, and fuels are used for all the power machines, and in repair work. For this reason, the combination building to include all of the shelter and repair requirements for the farm is often used. Such an arrangement is economical in the use of building materials, and convenient for handling the work. The principal objection to the combination is the increased fire risk. The danger from fire may be minimized by the use of fire-resisting materials and care in avoiding the accumulation of waste, shavings, or grease about the building.

CHAPTER XVIII

ICE HOUSES

THE country home has double use for ice, as compared to the city, for it is necessary not only to cool the products to be used in the house, but also to preserve the perishable products of the farm until they are marketed. The cost of the ice house is a small factor, and the labor of cutting and packing comes at a season when the regular farm work is not pressing. By attention to the principles of ice storage, practically every farm in the northern half of the country could provide a summer supply of ice with little cost. The saving in products, the better condition of meats, vegetables, and dairy products, and the fewer trips to market which are necessary will soon pay for the cost of the ice house.

FIG. 167.—A concrete ice house.

Types of Ice Houses.—There are three types of ice houses in common use, known as the pit, side hill, and above-ground house. The pit storage may be used where the soil is porous and well drained, and the land is rolling. The cost of this type is low, as the only cost is for the labor of digging and covering the pit. The side-hill type is possible where the land is sloping and a pit can be constructed in a side hill, affording drainage. A part of the house is built above ground. The house which sets entirely above ground is the common type, and is suitable for any locality. The houses of this type are usually more convenient, and the essentials are readily embodied.

Essentials of Ice Storage.—Regardless of the type of house, the three essentials of insulation, drainage, and ventilation must be embodied, to store properly the ice supply.

Insulation.—Insulation is the packing necessary on all sides of the ice block to exclude warmth, and to hold the cold within the pack. It is necessary to prevent, so far as possible, the circulation of air within the ice block—a minimum of ice surface should be exposed. The natural factors of shade and

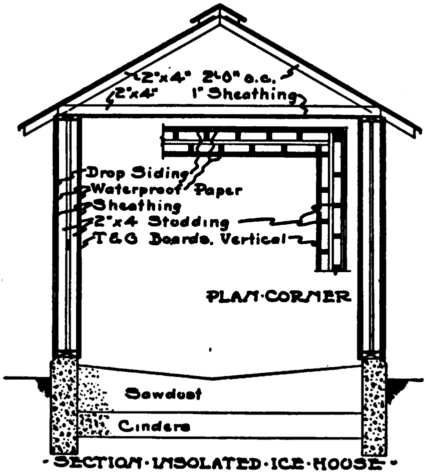


FIG. 168.—Section of an insulated frame ice house.

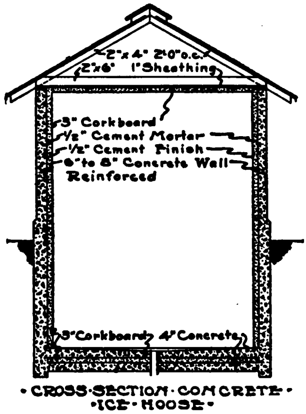


FIG. 169.—Section of an insulated concrete ice house.

a north slope should be considered in locating the house. The materials used to insulate the ice are chopped straw, sawdust, mill shavings, and commercial insulation, principally cork sheets and fiber sheets.

Chopped straw is the least effective, and should be used only when the other materials are not available. Sawdust is the most common and easily secured, and for average conditions, it is recommended. Sawdust is not effective when wet, and care should be taken to keep the material dry. Mill shavings are more porous than sawdust, hold more air in a given volume,

and for that reason are preferred to sawdust. From 18 inches to 2 feet of sawdust or shavings is necessary around the sides of the pack, and 2 feet at the top and bottom.

Commercial insulation in the form of cork, hair, or flax fiber sheets is light, easily handled, and efficient. The cost is higher than for the natural materials, but their use is increasing. The best use of commercial insulation is probably in connection with the natural insulating materials to secure the most efficient storage.

Drainage.—An accumulation of moisture is sure to result from the melting of the ice. If allowed to remain, the insulation is dampened, and the lower part of the ice block is likely to stand in water. This increases the rapidity of melting, and for good results the ice house must be drained. If there is a concrete floor it should be sloped to a drain in the center of the house. With the dirt floor, there should be a fill of cinders or gravel to a depth of 6 inches or more, to collect the moisture. In any case, unless the ground is very sloping, there should be a 4-inch tile drain away from the building.

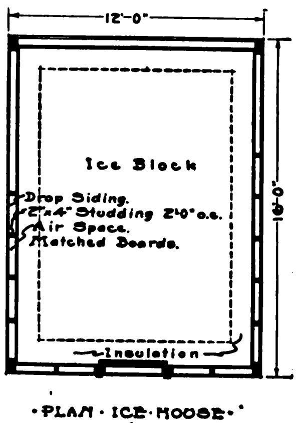


Fig. 170.—Plan of frame ice house.

Ventilation.—Although the ice pack should exclude all the air possible, it is necessary to have some circulation above the ice to dissipate the heat conducted through the roof on warm days. Openings between the rafters just above the plate, and a small cupola at the ridge will afford sufficient ventilation.

Space Requirement.—The United States Department of Agriculture found the shrinkage of ice to be from 30 to 50 per cent under farm conditions. In practice it is well to provide for a maximum shrinkage, and store double the amount of ice necessary. From 40 to 50 cubic feet of space is required to

hold one ton of ice. Ice weighs 57 pounds per cubic foot when solid, but only about 40 pounds per cubic foot as packed in the house. Ten tons of ice will require approximately 500 cubic feet of space for storage. For the purpose of insulation and convenience the actual space in the house must be greater than the actual requirement for the ice.

Assuming that 10 tons of ice is needed, provision should be made to store 20 tons to allow for shrinkage and waste. One thousand cubic feet of space will be required. The pack should be made as near the form of a cube as possible, to reduce the exposure to the minimum. A volume will be required, then, of 10 by 10 by 10 feet. Allowing 2 feet for insulation around the entire pack, a building 14 feet square and 14 feet to the eaves is needed.

Amount of Ice Required.—The farm requirement varies so greatly that no definite amounts can be specified. Average figures, secured principally from Farmers' Bulletin 623, U. S. Department of Agriculture, will aid in determining the amount that should be stored. The average household will use about 3 tons per season for miscellaneous purposes. To cool each pound of cream, and keep it at a temperature of about 40°, 1.16 pounds of ice is required. The cream from one cow can be cooled with about 500 pounds of ice in a season, although on many farms it is customary to allow 1000 pounds per cow. Cooling whole milk requires 1½ to 2 tons of ice per cow in a season. The requirements for the meats, fruits, and vegetables can be determined only by experience on the individual farm. The United States Department of Agriculture describes an 8 by 10-foot refrigerator which requires about 100 tons per year for cooling. In all cases it is well to store more ice than seems necessary, especially if it can be secured cheaply.

Ice-house Construction.—Most ice houses are of frame construction, and are no more difficult to build than the shop or garage building. In fact, the principles of insulation, ventilation, and drainage are of more importance than the type of structure. The best houses are of double-wall construction,

with 2 by 4-inch or 2 by 6-inch studding, sided outside, and ceiled inside the building. The wall space is then filled with sawdust or shavings and one or more layers of commercial insulation are added.

Hollow tile and cement blocks afford good ice-house construction, when insulated with fiber or cork. In any case a light concrete foundation is desirable for frame or masonry buildings.

A satisfactory ice house can be made by using 2 by 4 studding, and drop siding on the outside. The wall is not insulated, but considerable insulation is placed around the ice pack. The roof is usually of gable construction, with shingles or prepared roofing.

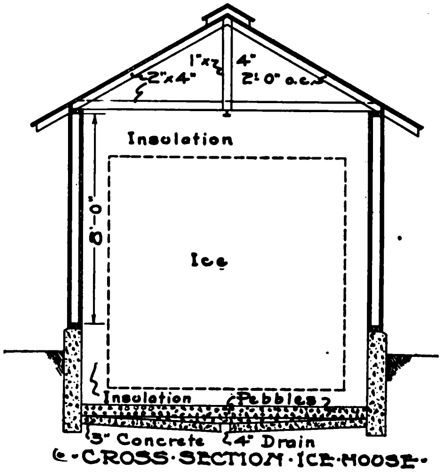


Fig. 171.—Cross-section of a frame ice house.

Ice Supply.—It is not the purpose of this text to discuss the source of ice, and the cutting and packing. It may be said, however, that the ice should be secured from a source free from contamination. Dirt or vegetable matter should be kept out of the ice. A clear flowing stream is preferable to a still pond as a source of ice.

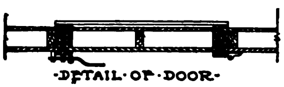


Fig. 172.—Detail of door for frame ice house.

It is often possible to make the ice from well or spring water by starting the cakes in a galvanized iron pan. After the shell has hardened, the center can be frozen later while the pan is used to start another cake. Where a commercial ice plant is convenient it may be possible to secure distilled water

ice cheaply in the winter season, and store it for summer use.

In packing care should be taken to have the cakes packed as closely together as possible, and the least possible amount of surface exposed to the insulating material. Cracks should be filled with small pieces, to avoid spaces through which air might circulate.

Cold water may be thrown over the pile of ice before the insulation is placed about it. This water fills the voids and cracks between the blocks and freezes, making the pile of blocks a solid mass of ice, thus reducing the exposed surface, which tends to prevent melting of the ice.

CHAPTER XIX

MINOR BUILDINGS

THERE are several buildings of minor importance in the farmstead group which should be discussed briefly. Few farmsteads will contain all of the minor buildings, although every farm has need for special buildings of this sort. They include smoke house, pump house, milk house or dairy room, spring house, scale shelter, seed house, and shelters.

Construction.—All of these structures are small, and the walls carry light loads. The foundation walls need not extend more than 12 inches below grade. The width should be 6 or 8 inches. The foundation should be carried above the grade line a few inches, in order to take the framing away from the damp ground.

Concrete is the best foundation material, and the trench will serve as the form. The best method of preventing heaving due to frost is to place steel reinforcing in the lower part of the foundation. A few inches of concrete should be laid in the bottom of the trench, and the reinforcing placed. Old steel may be used for this reinforcing. A 1 : $2\frac{1}{2}$: 5 mixture of concrete is sufficiently rich.

FIG. 173.—A smoke house built of hollow clay block.

Smoke House.—The average farm should cure much of the meat used, and a small smoke house is convenient and desirable. A size of 8 by 8 feet is sufficient.

The use of concrete, brick, or hollow tile is recommended, because of the fire risk. A concrete floor should be laid, and the roof may be of masonry. A smoke outlet is placed under the cornice. Hooks should be placed in the roof at the time it is made. The door should be of heavy plank.

Pump House.—For a deep-well system of water supply, or for a pump with jack, and engine or motor, it is desirable that a shelter be built over or near the well. If the house is directly over the well there should be an opening in the roof for removing the pump. This structure may be of frame or of masonry construction. It may be put to several other

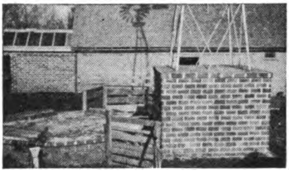


FIG. 174.—A pump house of hollow clay block.

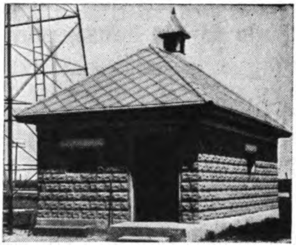


FIG. 175.—A milk house of concrete blocks.

uses aside from a pump shelter, such as storage of lawn and garden tools.

Milk House.—On the dairy farm, or where several cows are kept, it is desirable that a place be provided to keep the dairy equipment, such as churns, separators, coolers, and like material out of the basement or kitchen. A small house between the barn and dwelling and near the well will serve the purpose of caring for the dairy products. The house should provide for at least a cooling tank, or ice box, separator, churn, a stove or boiler, and the vessels used in milking.

Spring House.—The spring house may be used where running water is available. A milk-cooling tank is placed in the shelter. The floor is built low, so the spring water will flow into the tank. A shop or storage may be provided in a

story above the tank. The spring house is a building of the past century, but many of the old buildings are still in use.

Scale House.—The scale house is used in some localities to protect the scale platform and scale beam. The construc-

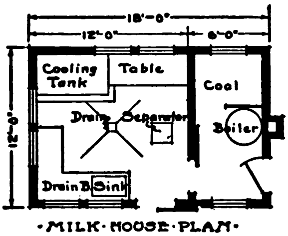


FIG. 176.

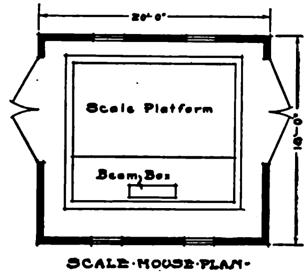


FIG. 177.

tion is of a gable-roof type, with large doors in the end, high enough to permit of driving on the scales with a load of hay. The scales are sometimes placed in the driveway of a building, as in the double crib.

Seed House.—If the farm seeds are housed in the residence, or in an outbuilding, it is usually inconvenient, a harbor for rats and mice, and the conditions may be unsuited to the storage of corn and grains. Where high-grade seeds are produced as a part of the farm business, the seed house is a necessity. The building may be small, of just sufficient size for the needs of the farm. Racks or hangers should be built, for curing the ear corn. Bins or boxes are used to store the

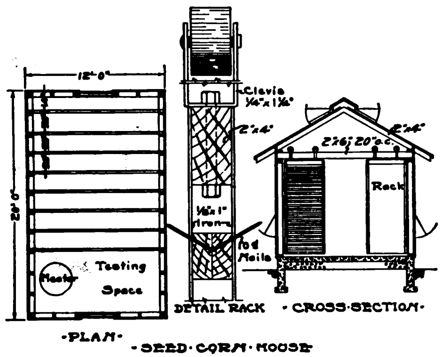


FIG. 178.—Plan and cross-section of seed corn house.

small seeds. A heater for drying the seed may be installed. The house should always be dry and well ventilated.

Shelters.—Farm animals require shelter during severely cold weather, winter rains, and sleet. Shade in the summer time must be provided by artificial means, if there are no trees in the pasture. An open shed, with the open side away from the direction of the prevailing winds, affords a good winter shelter for beef cattle, sheep, and hogs. The shed should be accessible from the feeding yards and permanent pasture.

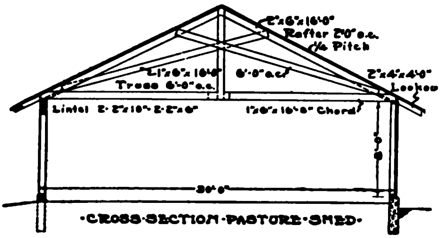


Fig. 179.

A roof, supported by posts or poles, affords a shade protection in summer. Dairy cows, fat cattle, sheep, and hogs all need a shelter from the sun.

A useful, cheap shelter often used is made by building

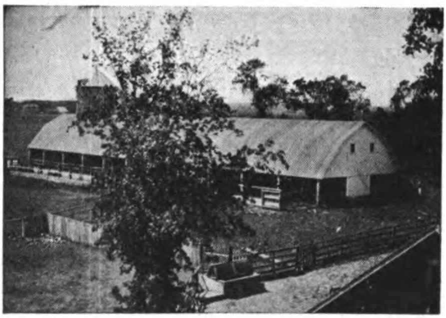


Fig. 180.—A general stock shed or shelter.

a framework of lumber or poles, loosely covered with poles or boards. At threshing time the straw from the machine is blown over the framework, and affords a very warm, convenient, and efficient shelter. This shelter may be renewed each year.

Utility House.—On many farms the owner desires to install modern conveniences, such as running water, electric lights, laundry and power-shop equipment, but the available buildings do not afford a desirable shelter. To provide a location for this equipment in one convenient place, a small utility house may be built near the dwelling. Such a building should be about 10 to 16 feet square, depending on the amount of equipment to be housed. A concrete floor and masonry side walls are permanent and easy to keep clean, and are not injured by moisture. The height should be about 8 feet. A gasoline engine, motor, line shaft, and articles requiring a small amount of power, such as washing machines, tool grinders, etc., may be placed in the utility building.

Combination Buildings.—In this text the essentials, plan, and construction of each building is discussed separately. In many cases it is possible, and desirable, to combine two or more separate buildings into one structure. Most farmsteads have more small buildings than are necessary, and the result is a farmstead of poor appearance. Two buildings, or several combined, may reduce the labor on the farm, make the work more efficient, lower the cost under that for separate buildings, and make possib e the use of permanent materials and better construction. Undesirable combinations should be avoided, but in cases where the equipment, uses, or operations carried on in separate buildings are similar, the combination may well be made. A few examples of possible combinations are: well house and milk house; laundry and milk room; tool shop and garage; shop and machine shed; ice house and vegetable storage; and garage and sleeping room for farm help.

Vegetable Storage.—The vegetable storage is not usually considered as a building, as the fruit and vegetables are, for the most part, stored in cave, basement, or in pits. The storage should be well ventilated, reasonably dry, and maintained at an even temperature, as near 40° F. as possible.

CHAPTER XX

HOME BUILT FARM EQUIPMENT

THERE are a number of handy and labor-saving conveniences for the farm, that can be constructed by the regular farm help in the winter season, or on days when field work cannot be done. No expert help is required, and a satisfactory job can be done by following the plans and suggestions given here.

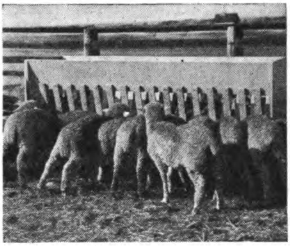


FIG. 181.—A feed rack for sheep.

The discussion will include feeding bunks and racks, feeders and feeding floors, tanks, waterers, breeding racks, pens, and crates. Practically the only tools required are the usual carpentry tools found in the farm shcp. Good, sharp tools, well cared for, will reduce the amount of labor necessary. The small amount of forge work needed may be hired, or done on the farm forge.

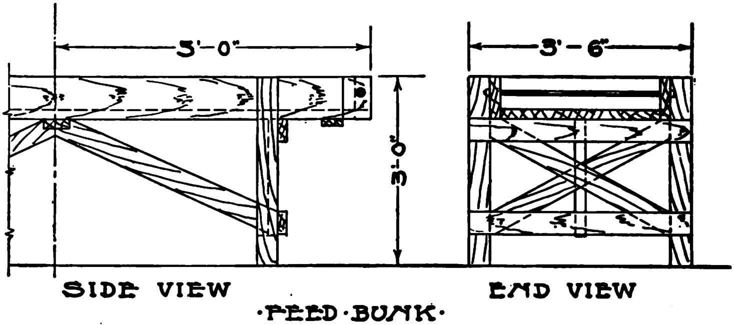


FIG. 182.—Details of a feed bunk for cattle.

Cattle-feed Bunks.—The size of the feed bunk ranges from 20 to 30 inches high, and 3 to 5 feet wide, depending on whether baby beef or mature cattle are fed. The bunk is made in any length desired, and should be of 2-inch lumber well

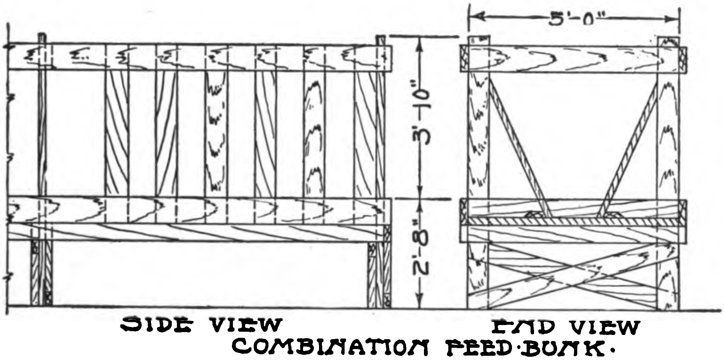


FIG. 183.—A combination feed bunk for grain roughage.

braced. The posts may be set in the ground, for stability. The bunks are used to feed grain and silage.

Feeding Racks.—The racks are somewhat similar in construction to the feed bunks. They are designed to feed hay and other roughage with a minimum of waste. The slats are spaced closely enough together that the animal can get but a mouthful of feed at a time. Racks are also made of poles, in several types.

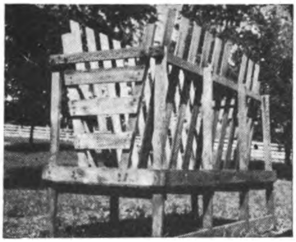


FIG. 184.—Roughage rack for cattle.

Mangers.—Mangers for stalls, pens, and feeding yards are made in a variety of styles, for different foods and feeding conditions. Horse and dairy barn mangers are discussed in Part I. They should be susceptible of easy cleaning, permanent, and comfortable for the stock.

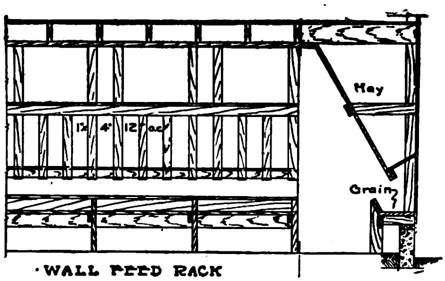


Fig. 185.—Details of a feed rack for a barn

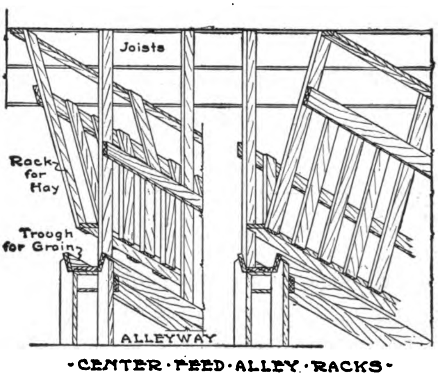


Fig. 186.—Feed racks to face center alley in barn.

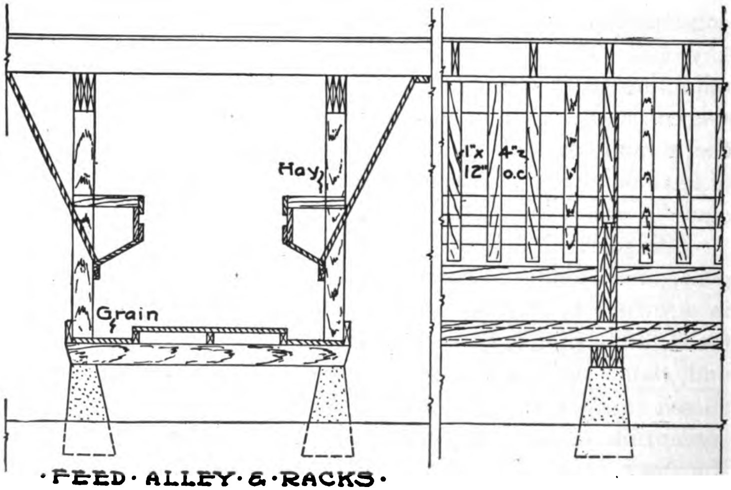


Fig. 187.—A center feed alley manger for cattle.

Feeding Floors.—The use of feeding floors, or paved barnyards is coming into quite general use among large feeders. The cleanliness and the feed saving resulting makes the liberal use of concrete for this purpose economical. The floor should be located on a well-drained soil, and given a pitch of $\frac{1}{4}$-inch to the foot to insure drainage. A fill of 8 to 12 inches of broken stone or gravel should be made, and compacted before the floor is laid. A one-course floor of 1: $2\frac{1}{2}$: 5 concrete is recommended. The floor for hogs should be 4 inches thick, and 6 inches for heavy cattle, and where wagons will be driven over the floor. A curb, 10 inches wide and 18 inches deep around the floor, will hold the edges, prevent their crumbling, and keep rats from burrowing underneath. It is well to reinforce the floor by embedding in it a heavy mesh fence wire. For hog feeding the curb should be carried a few inches above the surface to prevent waste of grain by rooting, and should be cast integral with the

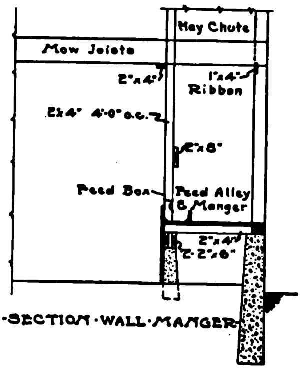


FIG. 188.—Detail of a wall manger for cattle.

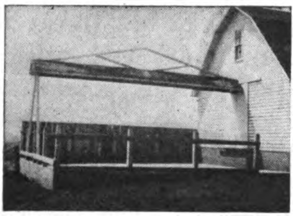


FIG. 189.—A feeding floor for swine.

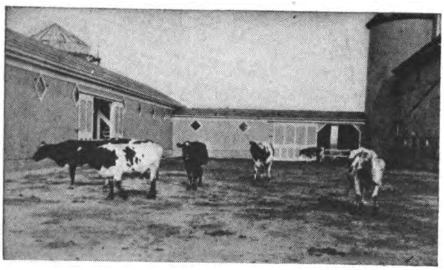


FIG. 190.—A paved barnyard.

floor sections nearest the edge. The floor should be poured in sections of about 15 feet square, and expansion joints pro-

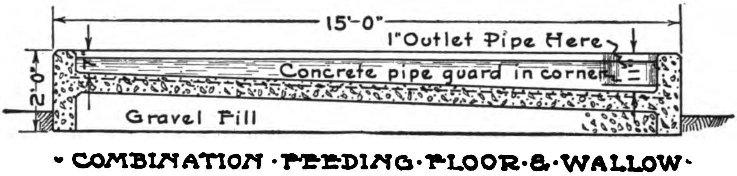


FIG. 191.—Cross-section of a combination feeding floor and wallow of concrete.

vided.. Fifteen square feet of floor should be provided for each hog, and about 35 for each head of cattle.

FIG. 192.—A mud wallow from a leaking tank.

Wallows.—During the hot, dry season the hogs require damp wallows to keep them comfortable and healthy. If no wallow is provided the damp or wet places in the pasture will be used by the hogs as a wallow, with consequent dirt, and unsanitary conditions. A concrete wallow, with fresh water supplied constantly, or at least once a day, affords ideal conditions. With some care the feeding floor, with a high curb, may serve as a wallow in warm weather, if supply pipe and drain are provided. The wallow should have a sloping

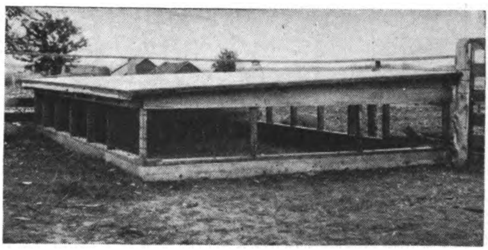


FIG. 193.—A shaded concrete hog wallow.

floor, and have water to a depth ranging from 4 to 12 inches. An overflow pipe connecting with a tile drain serves as an outlet. The outlet or overflow should empty into a sump or

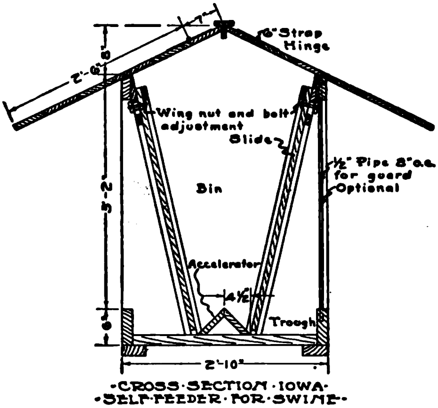


Fig. 194.

well outside the wallow, to settle out the sediment before the waste enters the tile. The supply may be from a spring, stream, or from the farm water supply.

Self Feeders.—The self feeder, or free-choice method,

Fig. 195.—Self feeder in use.

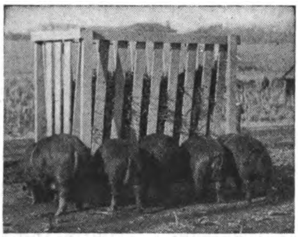


Fig. 196.—An alfalfa rack for swine.

by which the hog selects his own rations from several feeds, is advocated by a great many hog men. It has been shown that self-fed hogs make the quickest and most economical

gains. The labor saving makes the feeder a valuable piece of equipment.

The feeder consists of a bin which may be divided into

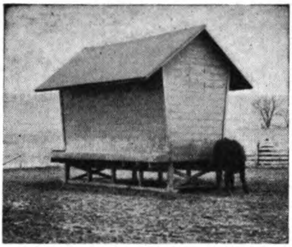


FIG. 197.—A movable self feeder for cattle.

FIG. 198.—A sheltered self feeder for cattle.

sections to hold one or more kinds of feed. A narrow, adjustable opening at the bottom allows the feed to flow by gravity to the trough. The feeder should be low and rather broad, for stability. An inverted, V-shaped trough under the opening from the bin, called an accelerator, tends to push the feed to the front of the trough. The trough should be made tight, and placed well under the bin for protection. Guards or covers are placed over the trough in some feeders. The feeders are made

FIG. 199.—A stock water tank.

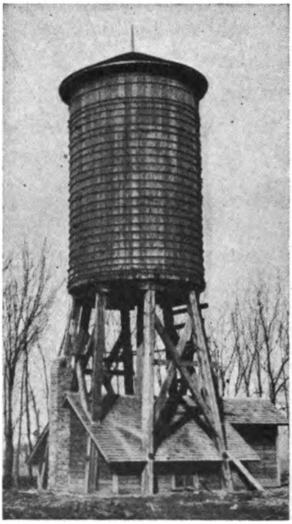


FIG. 200.—A farm water storage tank.

for small grain, mixed feeds and ear corn. Several compartments may be made in one feeder.

Larger, high feeders on the same principle are made for cattle. The trough is made 30 inches from the floor. Forage racks to hold several days' feed may also be used. These, together with waterers, will materially reduce the feeding work in the busy season.

Tanks.—The best water tanks for stock are made from concrete, both the round and rectangular shapes are used, the latter being preferable. The location for the tank should be well drained. A good foundation below the grade should

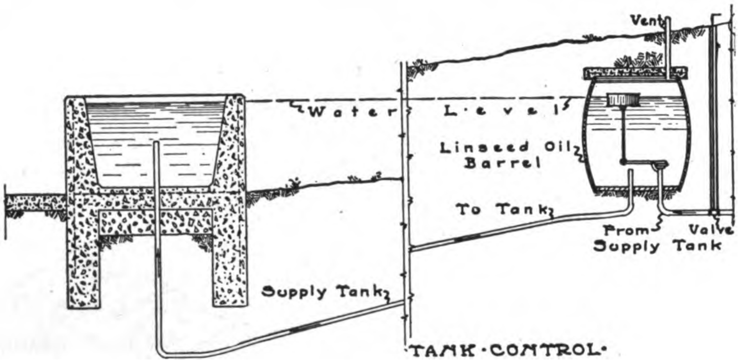


Fig. 201.—An underground float control for a water tank.

be installed, to prevent settling. The pipes and drain should be laid first.

The mixture of concrete for the tank should be 1: 2: 4, of a quaky consistency, spaded carefully to get a smooth surface next to the forms. When the concrete has set, the forms are removed and a wash given, of pure cement and water, mixed to a creamy consistency. Woven wire, well bedded in the concrete, and doubled around the corners, is used for reinforcing.

The sides of the tank should flare from 10 inches thick at the bottom to 5 inches at the top for tanks 2 feet or more in depth. This will prevent bursting from freezing, and gives the greatest amount of material at the bottom of the tank. A concrete floor for several feet around the tank is desirable.

The tanks may be covered with a wood cover, bolted to the sides, or by concrete slabs or a concrete dome. The concrete cover is heavily reinforced, using several steel rods in addition to the wire. Holes are made for the stock to drink through.

Hog Waterer.—A hog waterer of concrete, with a float chamber under the ground level, is convenient, easy to make, and will serve the purpose well. Heavy barrels may be used in place of the concrete, if desired. The plan shows how the waterer may be made. Protection in cold weather will reduce the chance of freezing.

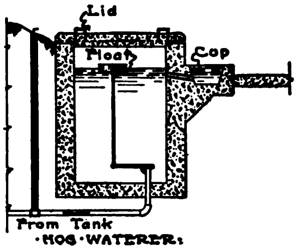


FIG. 202.—A concrete hog waterer.

The float control is used to keep the water in the drinking compartment at a constant level, when the source of the supply is at a higher level. The float is a tight chamber which remains on the surface of the water, and regulates an inlet valve, the level in the float chamber remaining the same as in the stock tank. A float may be placed in the tank, or at some distance away, and possibly underground for protection.

Hog-breeding Crate.—The use of the breeding crate makes possible the mating of animals which vary greatly in age, size, and condition. The plan shown has all the essentials of the more expensive commercial crates. The length is adjusted by dropping a gate through the top frame. The side adjustment is controlled by a lever arm at each side which moves the foot rest against the animal. The height is also

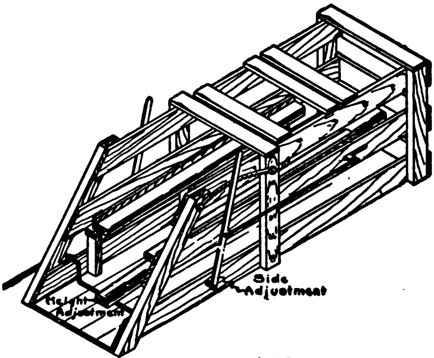


FIG. 203.

adjusted by a lever. The levers lock similar to the wagon-brake lever.

Cattle Breeding Rack.—The breeding rack serves the same purpose in cattle breeding as the swine crate for hogs, and

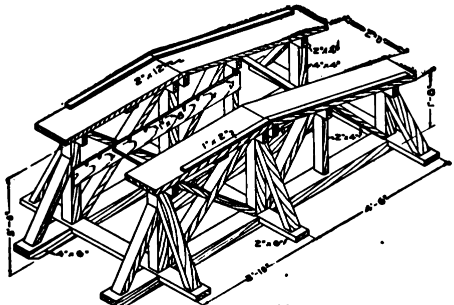


Fig. 204.—Breeding rack for cattle.

should be built to withstand hard usage. It may be used also for dehorning, hoof trimming, etc., if it is firmly anchored. Two-inch lumber should be used throughout. The rack may be placed on skids, to make it movable, or the posts can be set in the ground.

Corner Post.—To secure a strong fence, it is necessary that the corner posts be strong, well braced, and permanent.

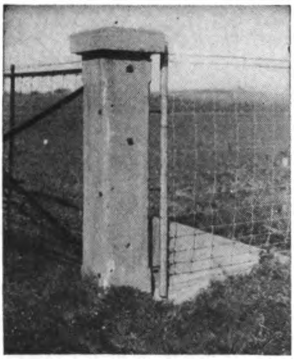


Fig. 205.—A concrete cornerpost.

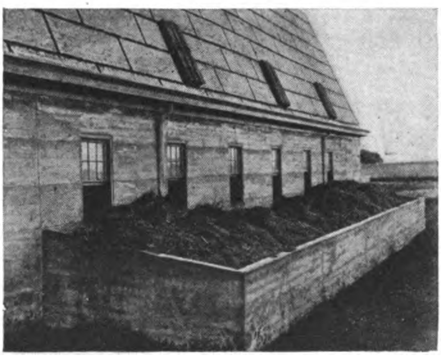


Fig. 206.—A concrete manure storage pit.

The factor of appearance should also be considered. Concrete meets the requirements for a good corner post. A rich concrete is used, and the post reinforced with 8 half-inch twisted square steel bars, which are covered by at least $\frac{3}{4}$ inch of concrete. The post should have iron pipe extending through in line with the fence, to receive the wire. The size of the post will depend on the height of the fence and the number of wires. It is best to cast the post in place, with braces, and a heavy mass of concrete below the ground line.

Manure Pit.—A concrete pit for the storage of manure conserves the fertility, prevents leaching, and lessens the trouble from flies. The storage in a pit makes a more sanitary farmstead. A concrete pit, with an inclined driveway, for easy entrance with a spreader, is recommended. A roof over the pit, screened sides, and litter-carrying machinery from the barn affords an ideal condition for handling the manure.

Scale Pens.—The scale platform should have a pen, or inclosure, for weighing stock. It is desirable that the inclosure be adjusted to swing out of the way for a load of hay or grain. In this plan the end gates hang on the pen sides, and the sides are hinged to the platform, to swing outward. Cross pieces at the ends hold the sides together when the pens are in use.

Shipping Crate.—For express shipment of stock, a secure

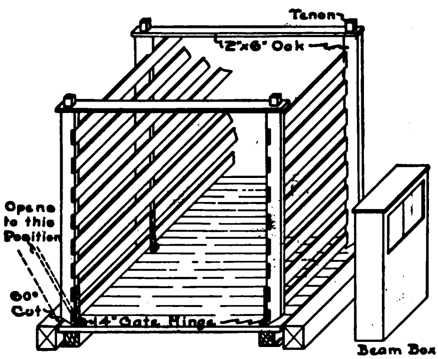


FIG. 207.—A scale pen with folding side.

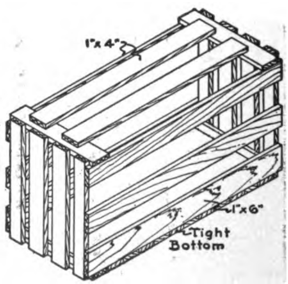


FIG. 208.

light-weight, comfortable crate is desired. A light, strong, wood is used, and the crate securely nailed. The floor should be tight, and the sides slatted. The crate is fitted to the animal to some extent, to prevent injury in transit.

Cattle Stocks.—The cattle stocks will find a wide use for

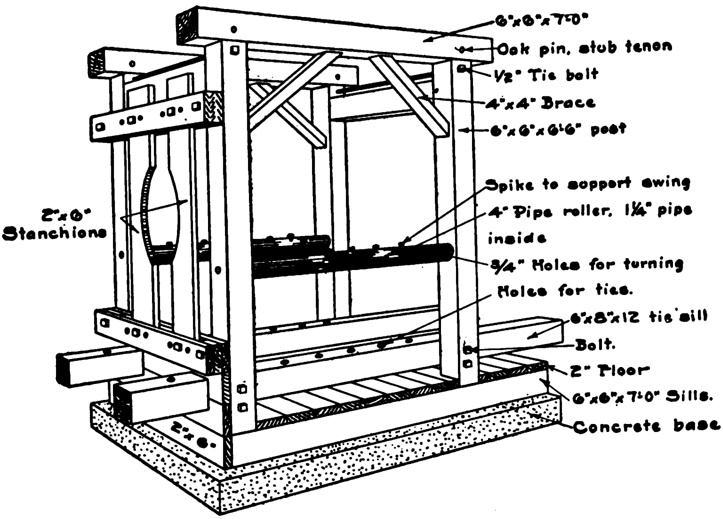


FIG. 209.—Cattle stocks.

safe and convenient handling of animals for dehorning, or veterinary treatment of any sort. The stocks should be located at a convenient point in the yards. Strong construction is needed, mortise and tenon joints, bolted, being preferred and a masonry base should be built.

Ringing Crate.—The ringing crate is a device for holding swine for the operation of ringing. It is a strongly built crate with stanchion in one end and gate or drop panel in

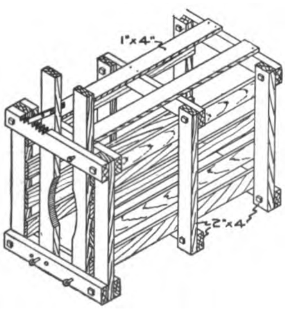


FIG. 210.

opposite end. It may be placed in hog run so the animals may be rung with greatest ease as they are driven through individually.

Dipping Vat.—The dipping vat is a container for holding

Fig. 211.—Dipping tank for stock.

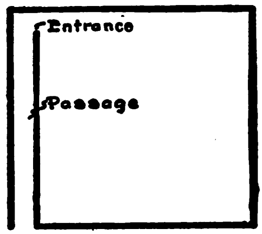
dip in which animals may be immersed for infection, ticks, and other pest insects. It is built of concrete and placed in an animal run for convenience. Drainage should be provided.

CHAPTER XXI

DEVELOPMENT OF THE FARM HOUSE

THE development of the farm house is closely associated with the progress of civilization, and dates back many centuries. The factors of climate, protection, poverty and riches, and the wandering instinct all have influenced the house at different times. After food, man's next need was for a shelter.

The nomadic tribes used limbs of trees, or a thicket of bushes for their early shelters. Later they used skins of animals, in the form of tents. Tribes limited to certain areas made more permanent shelters. Caves were cut in the rocks, houses were made from timbers, and in the Nile River valley mud huts were built. The earliest house plan on record is the primitive Egyptian house, of timbers.



·PRIMITIVE·HOUSE·PLAN·
FIG. 212.

The elaborate palaces of the Persian peoples, the pyramids of Egypt, the classic architecture of the Greeks and Romans, and the church and public building architecture of Europe are the outstanding features of the history of Architecture. Their influence on the American farm house, while not directly apparent, has been important. The best architects of farm homes have learned the principles of architecture of the ages, and apply the beauty, symmetry, and design of parts to the modern home. Some parts of the structure, such as the columns, follow directly the proportions and design of the Greek and Roman columns.

In America the development has been through the caves of the cliff dwellers, the "dobe" houses of the Southwest, and the wigwam of the Indian, to the pioneer home, the

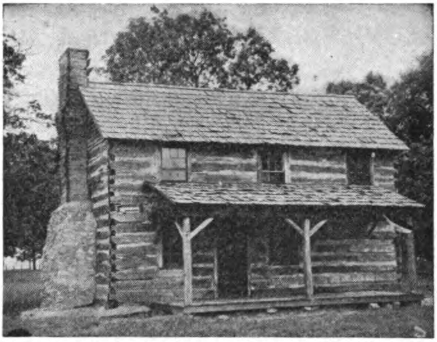


FIG. 213.—A log cabin.

frame shack, and the modern, convenient, well-equipped home of to-day.

The two types of farm houses most typical of pioneer

FIG. 214.—A large farm house in the middle west.

life were the log cabin and the sod house of the prairie. The log cabin had a huge fireplace, which furnished heat for cooking, warmth, ventilation, and oftentimes light at night. The heavy logs, with the crevices filled with clay, afforded a

warm, comfortable shelter and protection from wandering enemies. The needs of the pioneers were few, and the log cabin supplied them. The rough logs, wooded landscape, and the climbing vines afforded a picturesque beauty and comfort that is often lacking in the modern house. The sod house was made from the tough sods cut from the prairie, for timber was not available, the wooden door and frame being the only wood parts in many cases. The house was made low,

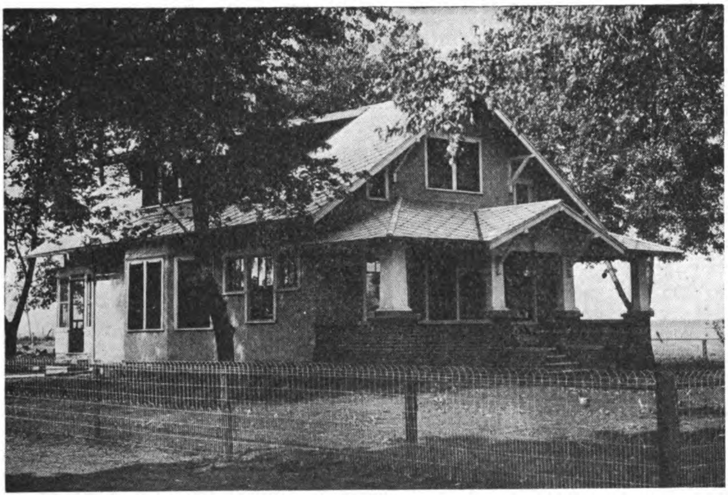


FIG. 215.—A farm house among trees, Central Iowa.

often partly underground, so the high winds of the plains did not harm them. The inside of the house was plastered, and the sod shanty also afforded a shelter that fulfilled the needs.

The architectural style of the modern home cannot be defined. It may be Colonial, Dutch colonial, Mission, or bungalow. In many cases it combines two or more styles, but more often the house has no defined style. If the house is simple in style plain, and substantial, and fits into the surroundings, it is likely to be suitable.

The "gingerbread" effect of years ago, and the towers, spires, and cupolas are gone from the house. The narrow porches, slender columns, high windows, and dark rooms have no place in the farm house built for beauty and comfort.

The ideal farm home is hard to find. The rapid settling of the country, the low prices for products, and the low price of land has retarded the development of the ideal type of house. Modern conveniences, care in planning, provision for comforts, and efficiency in arrangement are the things that will aid in making the farm home an ideal place in which to live. The incorporation of the owner's suggestions in the architects' drawings should result in a convenient dwelling.

CHAPTER XXII

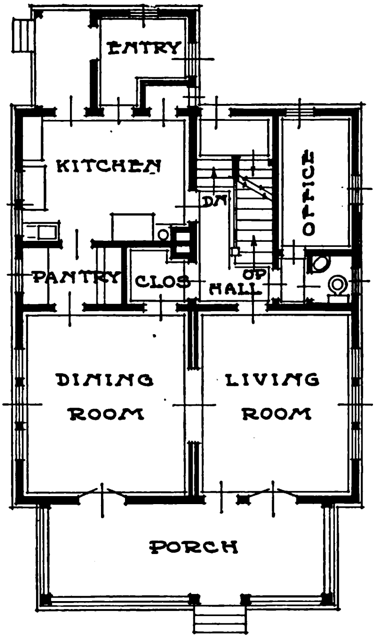
PLANNING THE FARM HOUSE

THE farm house is the most important building in the farmstead group, and its planning is often the most neglected. The house is a shelter for the child at birth, a protection and refuge during growth and maturity, and a comfort to the old man in his declining years. The farm home is the woman's domain, where she spends most of her time, in the care of the family, in the planning and serving of the meals and providing for recreation, rest, and sleep. The house is the business center of the farm; there the office is installed, wherein the business records are kept, and the business of selling and buying is largely planned there. Often the help is provided for, and sleeping rooms, wash rooms, and recreation rooms for the farm help maintained.

Most certainly the many problems of the home demand that the house plan be carefully considered. Every house is a separate problem, and requires separate treatment. There are very few plans which embody all of the features desired in the home, because the number in the family, the size of the farm, the amount of money available, the value of the farm, and the taste of the owner all affect the planning.

The architect is able to plan a house correctly, and avoid the mistakes which are sure to come from amateur planning. Yet the architect is often unfamiliar with the problems of the farm, and needs consultation with the farm owner. The ideal method of planning the farm home is by the co-operation of the owner, the architect, and the agricultural engineer, for through their combined efforts the problems affecting the design may all be met.

Since each house plan presents special problems, no attempt will be made here to designate each feature definitely, but rather, suggestions will be offered which will aid in the correct planning, with as many desirable features embodied as possible.



·FIRST·FLOOR·PLAN·FARM·HOUSE·

FIG. 216.

Parts of the Farm Home.—The discussion of the farm home may be made under the headings of the parts for the preparation and serving of food, recreation, administration, sanitation, service, and for sleep and rest.

PART FOR PREPARATION AND SERVING OF FOOD

This section of the house should include the kitchen, dining room, pantry, and the storage place for fruits and vegetables.

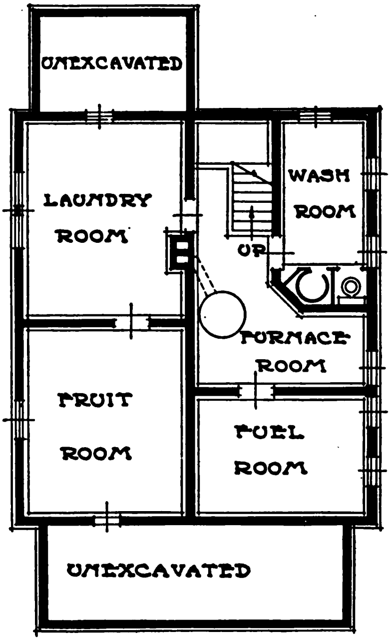
Kitchen.—A kitchen 11 by 13 feet has been found to be of good practical size for the farm. This size permits of the necessary fixtures, and room for two persons to work, yet is not so large as to cause unnecessary steps.

The kitchen should be a light, clean room, with windows on two sides, for light and ventilation. A location on a side of the house to overlook the barns and service yard is desirable. The range, sink, cupboard, and work table are the most important furnishings. The range should be placed near the flue, and opposite the windows, in order that it will be well lighted in the daytime. The sink should, if possible, be

placed against an inside wall, to protect the plumbing from freezing in cold weather. The work table should be placed under the windows, so that it is well lighted. The windows should be made high, with the bottom of the window 3 feet from the floor. The inclosed, built-in cupboard and refrigerator are desirable furnishings for the well-equipped kitchen. The housewife spends many hours each day in the kitchen, and convenience and comfort are very important.

The kitchen should connect directly with a screened, or glassed-in service porch, and with the dining room, or pantry. A direct entrance from the kitchen to the basement is desirable.

Dining Room.—The dining room should be ample in size for serving the large groups often necessary on the farm at threshing or silo-filling time. Thirteen by 15 feet or more is correct. The room should be well lighted, and a southern exposure is desirable. Built-in features may include buffet, china closet, and window seat. In many cases the built-in equipment is omitted from the dining room. The dining room should be symmetrical with respect to lines passing through the center of the room, as this plan lends itself to the best arrangement of the furniture and openings. The room is connected to the pantry or kitchen by a double swinging door, hinged on the side nearest the middle of the room.



·BASEMENT·PLAN·FARM·HOUSE·
FIG. 217.

The dining room usually connects to the living room by means of cased opening, colonnade, sliding doors, or French doors. The closed opening is the more desirable.

Pantry.—The larger farm houses often provide a pantry between the kitchen and dining room. It may contain the sink and cupboards. The pantry is an aid in serving when there is plenty of help available and many people to serve. A service room, or store room, may be built in connection with the kitchen, not as a serving room, but rather as a store room for the large amount of provisions to be kept in the home.

Fruit and Vegetable Storage.—In a majority of cases the fruit and vegetable storage is a part of the basement. The room should be kept dark and cool, and a northern exposure is desirable. Heating pipes in the storage room should be avoided, if possible, but if necessary, they should be well insulated. This room should be as far from the furnace room as possible.

Part for Recreation

The part of the house set aside for recreation consists of living room, or parlor, living porch, and library, or music room.

Living Room.—The living room should be large, comfortable, cheerful, and homelike. It is a place where the family may gather for enjoyment and good cheer. The old-fashioned parlor, with darkened windows and memories of the past is obsolete. The living room should be rectangular in shape and roomy. A room 14 by 20 is a convenient size, and is well adapted to the furniture, although the size may be varied greatly to meet conditions. A fireplace is a valuable addition to the living room. The room should have an outside door to the porch or terrace, and a connecting door to the hall or stairway.

Living Porch.—The modern porch should be planned for all the year use. A porch 8 feet or more wide, and of a length practically across the front of the house is desirable. Screens

should be provided for the summer, and sash for winter use. The porch should be carefully planned, to add to the appearance and value of the house.

The sun-parlor, or solarium, is an inclosed porch, or a room with the walls almost entirely of glass. Heat is provided, and the sun room is valuable for house plants, for "sunning" and if connected to the dining room, it affords a desirable dining porch.

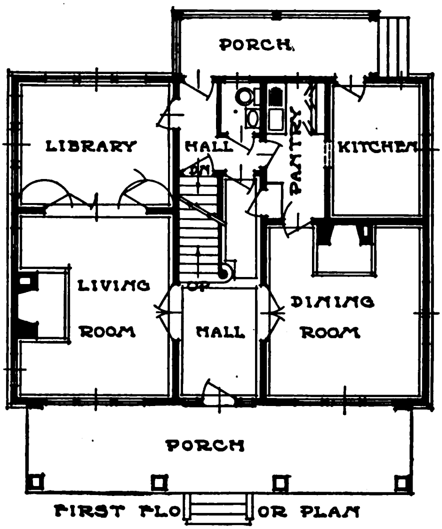


FIG. 218.—First-floor plan, house for village. See Figs. 220 and 221.

Music Room, or Library.—The library, or music room, or both, should be placed near the living room, and in a quiet part of the house. Plenty of clear wall space should be provided for cases and instruments, and comfort should be provided in every way possible.

Part for Administration

Farm Office.—The farm house is the business center of the farm, in most cases, and provision should be made to care for the business records and correspondence. The room should be accessible from the hall or stairs, away from the routine work of the house, and have filing cases, typewriter, book shelves, and desk, and should be furnished as a reception room for business callers. It is desirable that the room be located to afford a view of the barns and fields from the windows.

Part for Sanitation

The features included under the head of sanitation are the bathroom, toilet, washroom, and laundry.

Bathroom.—The bathroom should be 5 by 8 feet or larger, with an outside window to furnish light and ventilation. Only high-grade fixtures should be installed, with simplicity and efficiency in the plumbing. The bathroom may be placed on either the first or second floor; if on the second floor, there should be a toilet and lavatory on the first floor for convenience.

Toilet.—A toilet room, with closet and lavatory, should be provided, if possible, and on the floor not provided with a bathroom. With care in planning, the same soil stack can be used as for the bathroom.

Washroom.—The washroom is a desirable convenience, especially if there is farm help to care for. A location near the rear porch or in the basement is satisfactory. The plan should provide lockers, toilet, shower bath, and lavatory. The washroom with lockers makes it possible for the men to clean up and remove work coats, or change clothing, and avoid carrying dirt or stable odors into the living rooms. The washroom for help is considered almost as important as the bathroom in the large farmhome.

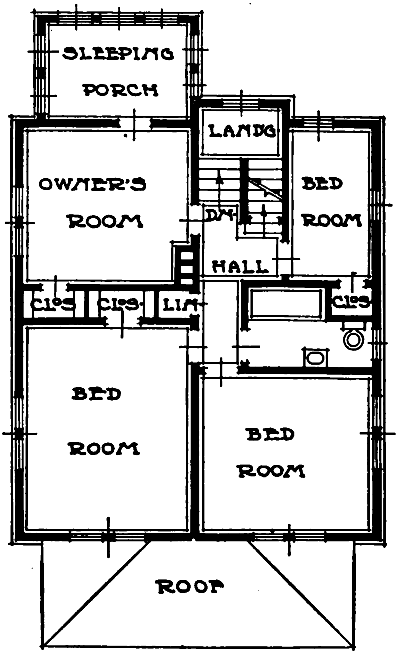
Laundry.—The modern laundry may be made sanitary and convenient, and the work lightened greatly over old methods of handling the wash. The laundry should be located in the basement, and the room provided with three or more windows. Stationary tubs, hot- and cold-water connections, and a laundry stove are necessary equipment. A concrete floor, with drain, is needed. The completely equipped laundry is fitted with power washer, fixed tubs, ironing machine, and electric flatiron.

Part for Sleep and Rest

Bedrooms.—The bedrooms should have cross ventilation, and two or more windows to each room. The plan should provide wall space for two possible locations for the beds.

A size of 10 by 12 to 12 by 13 feet is sufficient for the average bedroom. A spacious closet should be provided for each bedroom. The house for the average farm should have three bedrooms.

Dormitory.—For the care of help in the busy season of the year, it is necessary on many farms to provide a dormitory, or sleeping quarters for several men. A room in the third story, or a large bedroom, may be fitted with several beds for this purpose. This room should be provided with several windows, and good air circulation. In some cases the dormitory for the men is placed in a sales pavilion, over a garage, or in a separate bunk house.



·SECOND·FLOOR·PLAN·FARM·HOUSE·

FIG. 219.

Sleeping Porch.—The sleeping porch may be provided for by carrying the rear porch, sun parlor, or living porch to the full two-story height. The room should be wide enough for a clear passage about the beds, and should be screened in summer; it is usually "sashed in" for winter use.

PART FOR SERVICE

Stairs.—The stairs should be from 3 to $3\frac{1}{2}$ feet wide, and should usually be provided with a landing, to break the continuous flight from floor to floor. They should be designed for easy ascent, as discussed in the following chapter. Attic

stairs may be somewhat steeper and narrower than the main stairs. Basement stairs should be wide, since much material will be carried to and from the basement. All stairs should be provided with a hand rail, and attention given to the safety and comfort of those using them. The head-room should be at least $6\frac{1}{2}$ feet.

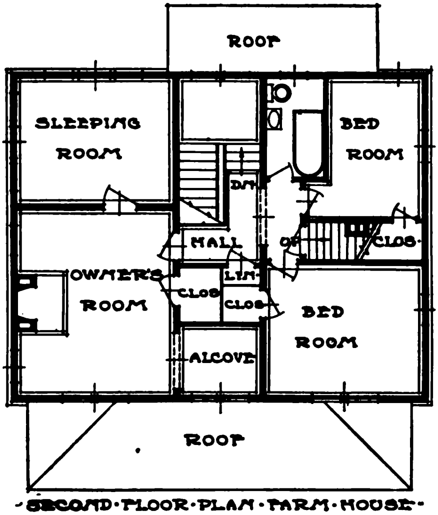


FIG. 220.—Second-floor plan of house shown in Fig. 221.

Halls.—A main hall through the house is often found, and is a convenience in passing to the different rooms. Doors should connect rooms direct to the hall. For stairs, the hall should be 6 to 7 feet wide for a two-run stair. The small hall or corridor at the head of the stairs should be 3 feet wide, and not longer than necessary to connect with the upstairs rooms. A reception hall at the front of the house is sometimes provided. The hall connects with the living room and the main entrance, and contains the stairway. In many cases the entrance hall is not necessary, and is simply a waste of space. A large number of house plans now omit the reception hall.

Closets.—Ample closet space is desirable in every house, especially in connection with the sleeping rooms and bath. Closets should be 2 feet 6 inches deep, and as long as possible, and have a door, shelves, and hooks. In a few cases it is possible to place a small window in the closet.

Basement.—The modern home requires a basement for the laundry, washroom, heating plant, storage, and utilities.

The basement should be excavated under the entire house, to a depth of 5 feet below grade, and 7 feet of headroom should be provided. Masonry walls and a smooth cement floor are essential. The floor should be given a slope, for drainage, and a floor drain provided. All basement rooms should have one or more windows. Partitions are placed to act as bearing walls for the partitions on the main floor, and divide the basement space. A fuel room in the farm-house basement provides the space to store a winter supply of fuel.

Grouping of Parts.—The square or rectangular house, with plain walls, is the most economical for space and materials. The preference of the owner will determine the exact size and shape, however. Since the house is a special problem, no further suggestions will be offered here, as to arrangement, except that the various parts should be planned together, for convenience, efficiency, and beauty.

Suggestions in Planning the House.—It should be the duty and pleasure of the entire farm family to take part in the planning of the new home. The following outline of the method of planning will be of help. The chapter on Plan Drawing should be studied in this connection.

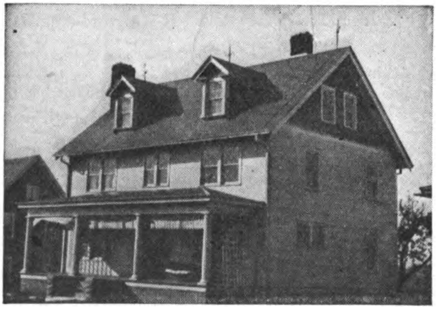


FIG. 221.—House in small village. See Figs. 218 and 220.

1. Select location.
2. Determine the number of rooms desired, for present and future needs, and select roof shape.
3. Decide upon shape and possible size.
4. Locate kitchen with exposure and view desired.
5. Locate dining room and stairs, with reference to the kitchen.

6. Plan living room with reference to dining room and hall.
7. Utilize remaining space for office, bedrooms, etc.
8. Decide upon size of rooms, and plan for economy of materials.
9. Plan doorways, leaving space for furniture.
10. Locate windows, selecting stock sizes.
11. Plan porches.
12. Plan arrangement of second floor, with reference to stairs, hall, and bearing walls.
13. Plan basement, using partitions as bearing walls for first floor.
14. Study front and side elevation views for proportion, mass, shape, and symmetry.
15. Group windows in elevation for appearance.
16. Change windows in plan to fit elevation.
17. Make plans in pencil, to scale, with dimensions.
18. Trace plans and elevations.
19. Locate plumbing, lighting, and heating fixtures.
20. Draw details of construction and complete drawings.

CHAPTER XXIII

FARM-HOUSE CONSTRUCTION

THE construction work on the farm house should be done by experienced carpenters and masons. The student and owner should, however, be familiar with the best methods and practices of construction, in order that they may properly design and superintend the erection of the house. The work is more complicated than the construction of barns and outbuildings, and more care is necessary to secure good workmanship on the finish and trim.

Types of Construction.—Houses may be of wood or masonry construction. The frame building may be full frame, half frame, or balloon frame. Most houses of the present day use the balloon frame entirely, when built of wood. Masonry construction may be brick, tile, stone, or concrete. The brick veneer and stucco houses are usually framed with wood, and the permanent covering placed over the frame.

Since the frame house is the most common at the present time, this type will be discussed quite fully in the following pages. The masonry houses, as a rule, use the same methods of inside construction, millwork, and finish.

Foundation and Footings.—The foundation wall is made of masonry, such as brick, stone, hollow tile, or concrete. The thickness of the wall depends on the materials used, ranging from 8 inches for the tile and concrete, to 13 for brick, and 16 inches or more for stone. The wall should extend 4 to 5 feet below grade, and 2 to 3 feet above grade for a 7-foot basement; above grade it should be finished with a brick or stucco exterior, or by pointing up the cement or tile blocks.

The lower part of the wall should rest on a spread footing

of concrete to prevent settlement. The footing should be about 6 or 8 inches thick for the average wall, and 14 to 16 wide. The condition of the soil will determine the exact size. In a wet location the outside of the wall should be smooth, and covered with a waterproofing compound, to prevent the conduction of moisture. A 4-inch drain tile around the foundation may be necessary to carry away the excess moisture.

Balloon Frame. — This construction makes use of the box sill, and vertical studding 2 by 4 inches in size. The top of the studding is covered by a plate, to which the rafters are nailed. No heavy framing or large pieces are used. Studding are doubled or tripled at the corners, and doubled around openings.

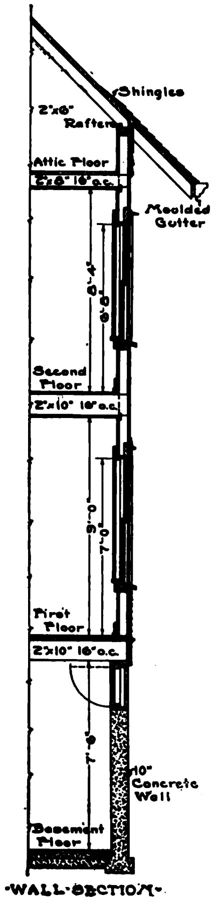


FIG. 222.—Wall section, frame construction.

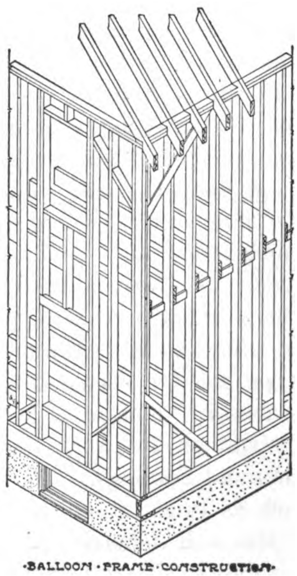


FIG. 223.

Sills.—The box sill, in one of the types illustrated, is used in the usual construction. A bed or wall plate, 2 by 6 inches up to 2 by 12 inches is used, depending upon the thickness of the foundation wall. The edges are set flush with the outside of the wall, or may be 1 inch inside the edge, so the sheathing will be flush. The joists rest on this plate, and the studding may rest on the plate and be fastened to the joists or may be set on a plate over the sill and on the subfloor.

Joists.—Floor joists for the first floor are 2 inches thick, and 2 by 8 or more in size, depending on the span. The usual spacing is 16 inches apart on centers. The joists should be made level on top to give a smooth surface to the floor; they are sized at the ends, or shimmed up, so they are all level.

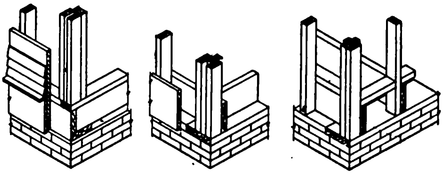


FIG. 224.

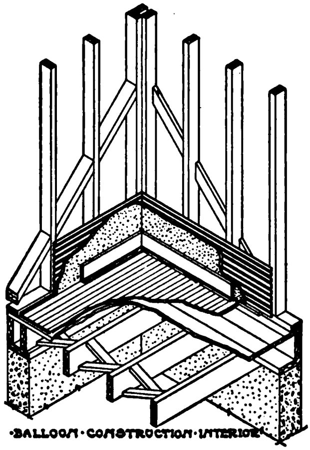


FIG. 225.

Girders.—In most cases it is possible to locate the cellar partitions so they act as a bearing for the joists. If this is done, a 2 by 6 inch plate is sufficient. Where needed, the girders are usually made up of 2 by 10-inch material, as wide as needed. The joists are rested on a bearing strip spiked to the girder, or hung with metal joist hangers. The girder should be continuous between walls, and supported at intervals of 8 to 12 feet.

Bridging.—All joists should be trussed or braced between bearings to distribute the load and stiffen the floor. The bridging used for this purpose is 1 by 3 material cut to fit

diagonally between the joists. All spans under 13 feet should be bridged once in the span, and greater spans are bridged at two points. Before the bridging is secured, the joists should be spaced at the top and bottom. The bridging must be nailed at the top before the subfloor is laid.

Studding.—The vertical wall members are 2 by 4 inch, set 16 inches apart on centers. The lower end rests on the sill or shoe, and the upper end is secured by the wall plate.

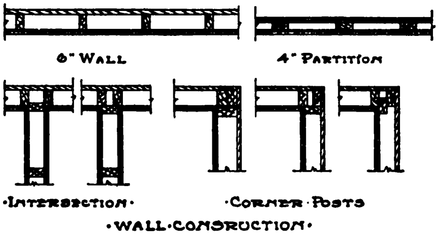


FIG. 226.—Detail of walls and partitions.

Method of Raising.—The corner posts, made up of three pieces of studding, are raised, plumbed, and stayed in position. The ribbon or ledger board is placed in position, and the intermediate studding are set in position after they have been notched for the ribbon. The bottom of the studs are toe-nailed to the sill, and the tops are covered by the plate, and nailed. Window and door openings are located, and the studding cut out, and headers and sub-sills set for the windows. Large openings are trussed over the opening, to support the weight above. Interior studding is set to form a 6-inch wall, and the studding placed 16 inches apart, or as necessary for the openings. For non-bearing walls, the studding is sometimes set flat, to save space. The narrow wall is commonly used in closet construction. The corners of the house are braced by diagonal 2 by 4-inch braces, at an angle of about 60° with the sill. Diagonal sheathing is often used to stiffen the house.

Sheathing.—The sheathing is 1-inch material, either plain boards, or shiplap, fastened to the studding, with eight-penny nails. A stronger construction is secured by placing the sheathing at an angle of 45°. The extra cutting and material used has led to the use of horizontal sheathing for the greater part of the work.

Water Table.—The base course extends around the building on the line of the floor joists. It is placed outside the sheathing, and supplies the connecting trim between the masonry foundation and the siding.

Siding.—The exposed outer covering of the house is made of thin clear boards, placed over the sheathing, or over the studding in some cases. The siding is usually lapped, or placed in shingle effect. Lap or beveled siding is the most common type. Patented or drop siding is sometimes used on cheap construction. As a rule, building paper is placed between the sheathing and the siding, for warmth. Shingles are also used for the covering, and are placed similar to the roof shingles, except where a wide exposure of 5 or $5\frac{1}{2}$ inches is given. Stucco over the sheathing, over wood or metal lath, or patented lath may be used.

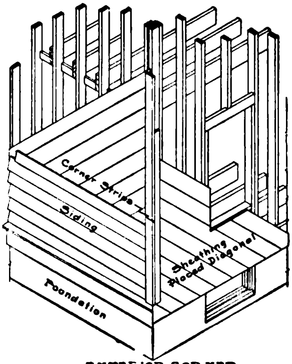


FIG. 227.—Exterior corner, frame construction.

Lath and Plaster.—Plaster is used to cover the inside walls of the entire building in the first and second stories. The lath are usually of wood, $\frac{3}{8}$ by $1\frac{3}{8}$ inches, by 4 feet long. They are spaced about $\frac{3}{8}$ inch apart, or the thickness of the lath. A 4-foot lath covers three spaces between studs. Joints should be broken every 16 to 18 inches. The best lath are made from white pine.

Lime mortar was formerly used entirely for plastering. Three coats were used, the lath coat, scratch coat, and the skim coat. Several weeks were required to allow the plaster to dry between coats. The surface was hard, and adapted to the use of wall paper. Patent plaster is now used almost exclusively, and must be applied exactly according to directions. Two coats are often used, the first coat including the former two of the lime plaster, and the finish coat is sanded for exposed wall, or hard finished with Keene's

cement or lime putty without sand for use in bathroom and kitchen.

Lath and plaster are measured by the square yard, and no deductions are made for openings. The placing of the plaster should be done by experienced plasterers. All surfaces should be true, and corners straight. Grounds are used to keep the thickness.

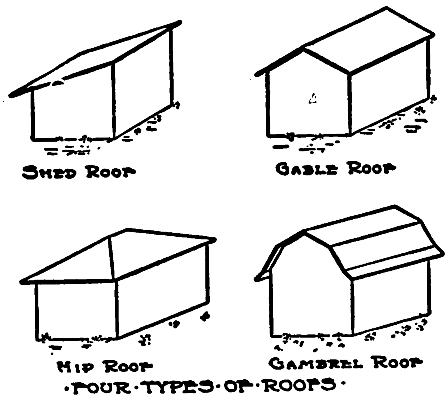


Fig. 228.—Common shapes of roof.

Roof Construction.—The most commonly used roofs for farm buildings are the gable, hip, and gambrel. In the gable roof, the two slopes are equal, and the rafters may all be cut from the same pattern. The gambrel roof is not widely used. The hip roof requires experience in rafter cutting to secure the correct framing.

The amount of slope or steepness is called the pitch. The common pitches are $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$. Rafters are spaced 16 inches to 2 feet apart on centers, and are 2 by 4 or 2 by 6 inches in size, depending on the span and the weight of the roof. In a long slope the rafters are supported between the plate and the ridge by a purlin. The cutting of the rafters is the most important part of the roof framing. See Chapter XXXV.

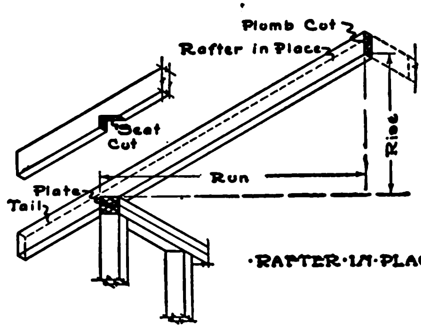


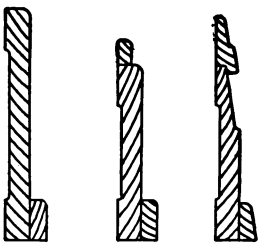
Fig. 229.—Illustrating terms used in connection with rafters.

Sheathing for Roof.—For slate, composition roofing, or asbestos shingles, the roof sheathing is made practically tight, as on the side walls. For wood shingles, the sheathing may be solid, or made of 1 by 4 inch material, spaced 2 inches apart.

Flooring.—The floor joists should be covered with plain boards or shiplap, to form the sub-floor. This floor is laid diagonally to add strength, and to avoid cracks showing in the finish floor. The subfloor is used to work on during the construction, and is laid as soon as the joists are set. In laying, each end should come directly over a joist.

The finished floor is laid after the standing trim is in place, and may remain undisturbed until finished. The best flooring is $\frac{13}{16}$ inch thick and is laid over a subfloor, or in cheap construction is laid directly on the joists. A thin flooring $\frac{3}{8}$ inch thick, is made in several of the hardwoods, and is largely used to cover old floors, but is also used to afford a hard surface on new work. The exposed face of the flooring is narrower than nominal width, and there is considerable waste in placing it. The best flooring materials are yellow pine, fir, maple, and oak. Quarter sawed, or edge-grain material is usually better than the flat sawed.

Interior Finish.—The interior finish or standing trim consists of window and door casings, baseboard, moldings, etc., of either hard or soft woods. The finish is purchased in random lengths and cut on the job, or is made in units sufficient for each opening or wall. Finish lumber should be clear and free from defects and protected from the weather, and be smoothed and sandpapered before being placed. The nails are small-head finishing nails, and should be set, and the holes puttied before the paint or varnish is applied.



·COMMON·TYPES·OF·
·BASEBOARDS·

FIG. 230.

Millwork.—The built-up work, such as doors, window frames, panels, stairs, etc., is known as the millwork. The

millwork is all made by machinery, and many companies make a specialty of this work for houses. Stock or standard sizes should be secured so far as possible to avoid extra charges. A discussion of millwork sizes is found in Chapter XXVII.

Door Frames.—The frames are cut at the mill and nailed together on the job. The material is $1\frac{3}{8}$ inches thick, and the frame is rebated for screen and door. Inside door frames

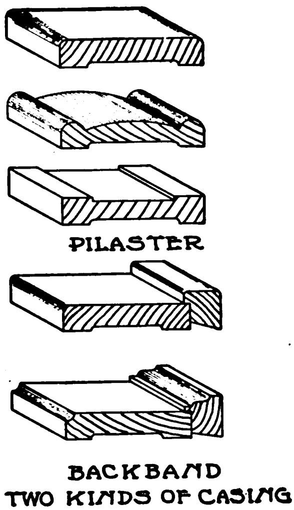


Fig. 231.

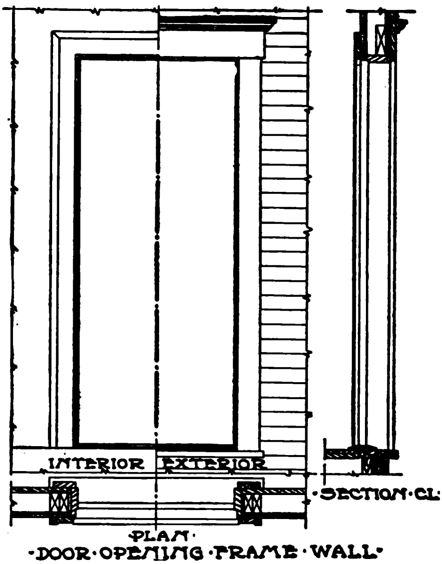


Fig. 232.—Detail of door opening, frame construction.

are made from 1-inch dressed material, placed after the plaster is dry. The doors inside fit against a stop molding on jambs.

Window Frames.—Frames for windows are made to suit the various kinds of wall construction. The principal kinds of frames are those for cellar windows, casement windows, and the usual doublehung window. The cellar window is low, being made to fit between the grade line and the water

table. The sash is usually $1\frac{3}{8}$ inches thick, having three lights, ranging from 8 by 10 inches to 10 by 16 inches. Casement sash are made to swing either in or out, and the screen must be placed to allow the window to open. The sash is hinged on the side and must be quite strong. Care is necessary to secure a tight fit, in order to prevent leakage in heavy rains.

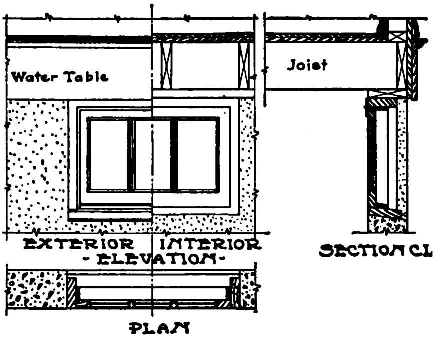


FIG. 233.

The double-hung window is the common type used. The two sash slide past each other, and are counterbalanced by weights. The check-rail window, in which the center rails overlap, is the best type, though in cheap construction the plain rail is used. The two sash may be made plain, of clear glass, the lights divided into several panes if desired. A common method is to use a plain glass in the lower sash and divided top light, the divisions being available in a variety of forms. The size of the window is designated by the size of glass in the lower sash.

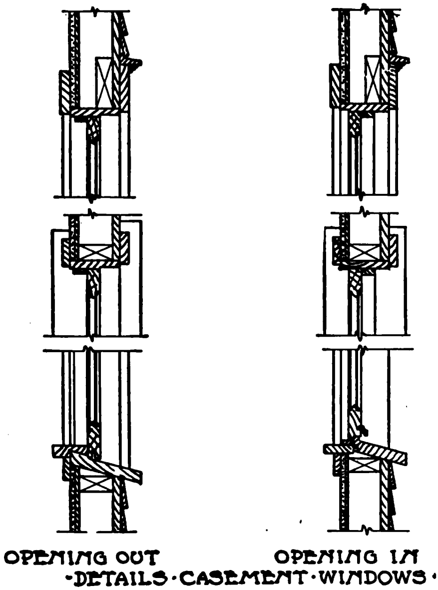


FIG. 234.

Care should be taken to have the frames plumb and true and the heads of the windows all on the same level. The casings should be made of $1\frac{1}{8}$-inch material, and the sash $1\frac{3}{8}$ inches thick.

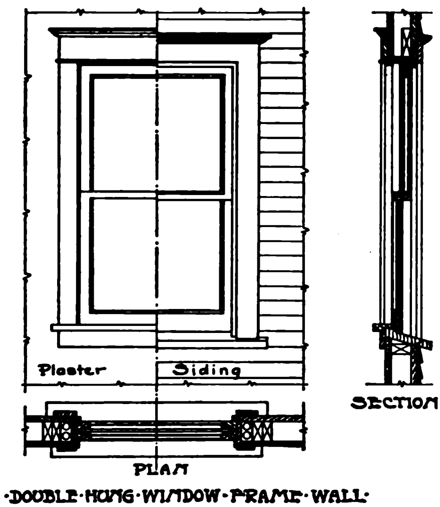


FIG. 235.

Stairs.—The flat part of the stairs is known as the tread, and the vertical part as the riser. For an "easy" stairs, there is a definite relation between the treads and risers. The product of the tread and riser, in inches, should not be less than 72 nor more than 75. The sum of two risers and one tread should equal 25. A rise of $7\frac{1}{2}$ inches

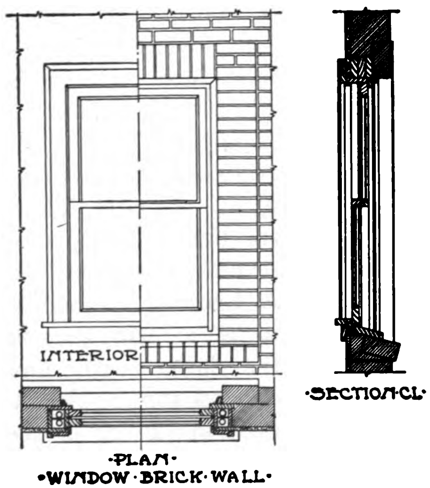


FIG. 236.—Details of window, brick wall.

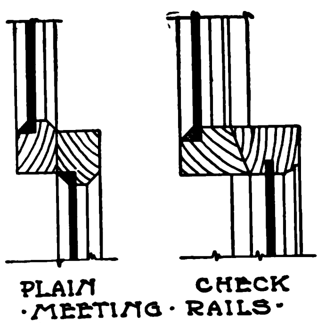
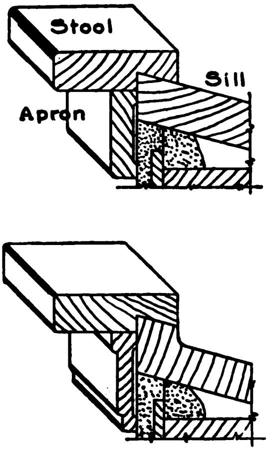
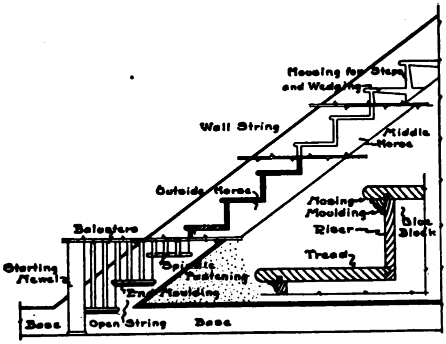


FIG. 237.—Meeting rails, double-hung window.



•DETAIL·STOOL·&·APRON•

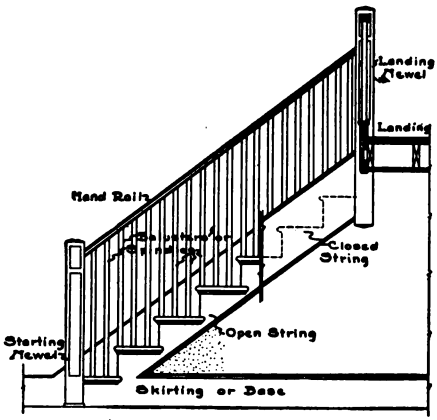
FIG. 238.—Details of window sill, stool-and apron.



•STAIR·DETAILS•

FIG. 239.—Stair details, illustrating terms used for various parts.

and a tread of 10 inches is a good proportion. In the usual construction there are 16 risers between floors. The risers are supported by horses or strings, one on each side of the stairs. Stairs may be open or boxed, the former being usually finished better, as they open from a hall or living room. Balusters and railing, and newel post at the bottom are used with this type. Boxed stairs are inclosed on both sides.



•STAIRS·&·VISIBLE·PARTS•

FIG. 240.—Elevation of stair.

Stairs are usually built in two or more flights or runs, with a landing between, which is square or rectangular, and

may be used for a turn. Winders should not be used in the modern house. Headroom of 6½ or 7 feet is necessary for the stairs.

Stair building is a highly specialized trade, and a full discussion is not possible here.

Cornice.—The open and the boxed cornice are used in farm-house construction. In the open cornice, the rafter

FIG. 241.—Stairway in house shown in Fig. 218.

ends are surfaced, and left exposed. The half-round or box gutter is used. The sheathing is exposed under the projecting part of the roof, and is made of ceiling lumber, nailed without spaces.

The box cornice is used on porches, and on many houses. The gutter is built into the cornice, and the rafter ends are boxed in. The gutter is usually made of boards, lined with tin or copper.

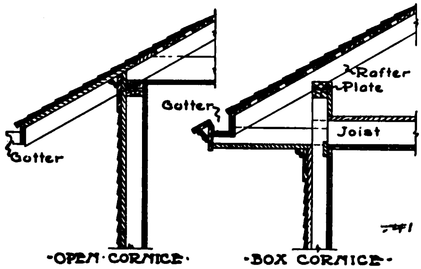


Fig. 242.

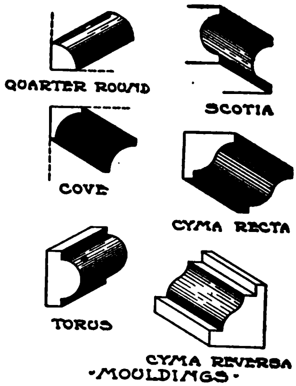


Fig. 243.

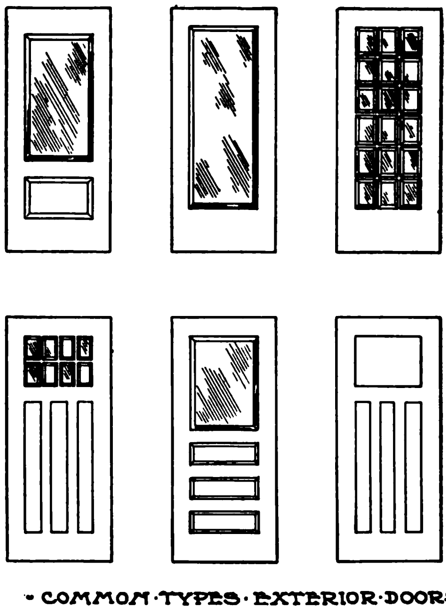


Fig. 244.

Moldings.—There are several forms of moldings used in the trim of the house, the more common of which will be mentioned. The quarter round is used for the carpet strip, between the floor and the base. The concave molding, the opposite of the quarter round, known as cove, is used between the wall and ceiling. The convex, half-round molding is called the torus, and is used as a necking mold in columns.

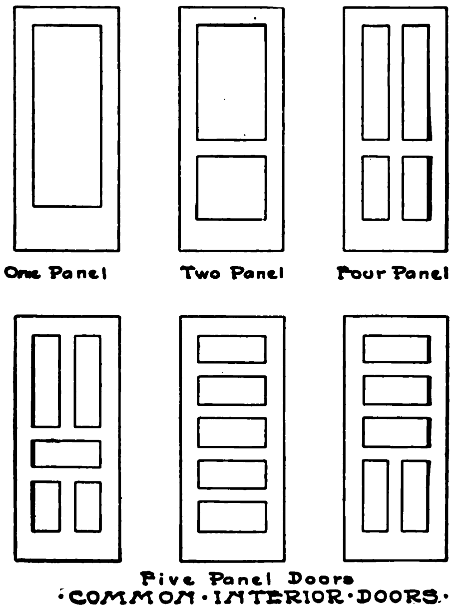


Fig. 245.

The concave molding, or scotia, is used between two torus moldings. The ogee molding is used for both base and crowning members. Other moldings are back-band trim, door and window stops, picture mold, base mold, etc.

Other Terms Used.—There are several commonly used terms in connection with interior finish and millwork which may be mentioned briefly. Standing trim refers to finish lumber placed around openings or on the walls. The trim

is backed, or cut out on the back, so it will fit snugly against the wall. Casing refers to the trim around the openings. The back-band trim has a molding around the trim, to cover the rough edges of the material, and form a smooth fit against the wall. The pilaster casing has both edges of the trim the same, and a plinth block, against which the bottom of the trim and the base terminate. Window stool and apron are the two members at the bottom of the window. The base is the trim member around the lower part of the wall. Interior finish is made in a wide variety of styles, and under several trade names. A simple trim, free from irregular surfaces, and easy to keep clean, is to be desired.

Wood Finishes.—The most common methods of finishing the interior woodwork are by waxing, varnishing, or painting.

Wood may be finished in the natural, by sanding the wood, and using wood filler, clear shellac, wax, or varnish. Stains may be used to bring out the grain, and imitate rare woods.

The best method of waxing is to use a wood filler with two coats of shellac and a good grade of floor wax. For varnishing, the wood is stained, then given two or more coats of varnish. The final coat of varnish may be rubbed, or a dull finish varnish bought, to give a finish without a high gloss. Coarse woods, such as oak, should be given a coat of paste filler to fill the pores. The filler is rubbed off as soon as the gloss has left it, and may be applied with the stain on porous woods. Painting is desirable for bathrooms and kitchen, in order that the woodwork may be washed, enamel or gloss paint being used. Five coats are necessary for satisfactory enamel work.

CHAPTER XXIV

THE TENANT HOUSE

Living quarters for hired single men, married help, or renters are classified as farm tenant houses. The increasing number of farms employing married help, and the better satisfaction on the part of both tenant and owner when the help has separate quarters, has led to a definite demand for the tenant house.

Industrial housing has been undertaken on a large scale during the past few years, with marked success, and the development of the farm tenant house is along the same line. Practical farmers agree that the tenant house on the farm enables them to secure and keep a better class of help and get more efficient labor.

Fig. 246.—Square tenant house in Iowa.

Whether the married tenant is a share renter or a hired man he requires comfortable living quarters, a garden, and a place in which to keep a few chickens and a cow.

As a rule, the tenant house is not so complete as the farm home, and is constructed at less cost. It is possible, however, by careful planning to secure comfortable, attractive, and practical houses for the farm workers.

Location.—The tenant house should be located away from the barns and outbuildings, but not closer to the road

than the main house. The house should have a sodded lawn, and shade trees, and be made as attractive as possible by planting.

Size.—As a general thing, the tenant house may be smaller than the farm house, and the rooms may well be on one floor. A 6-room house or less is usually sufficient. The house that is nearly square in plan is the most economical, and the square or rectangular house may be used to advantage.

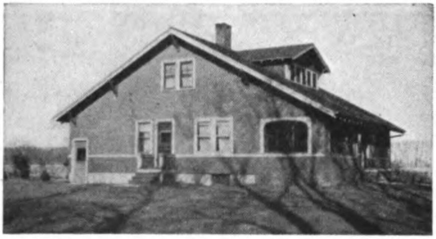


FIG. 247.—Foreman's house on large western Iowa farm.

Arrangement.—The arrangement of the rooms will depend upon the space available and the size of the house. The kitchen should connect directly to the dining room and rear porch. The dining room should be of sufficient

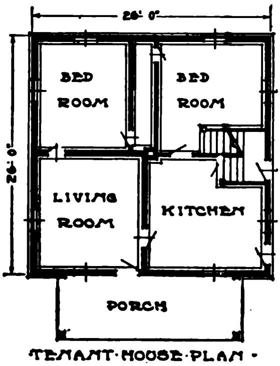


FIG. 248.—Plan of square tenant house.

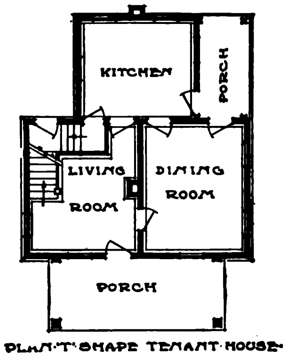


FIG. 249.

size to care for extra boarders. Porches and sleeping rooms should be compact, but of convenient size.

Kitchen.—The kitchen should be at least 10 feet each way, with wall space for range, sink, built-in cupboard and

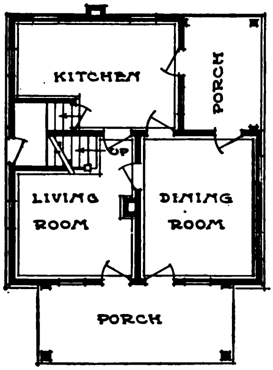
work shelf or table. The room should have two outside exposures, and cross ventilation.

Dining Room.—The dining room may be combined with a large kitchen or large living room if convenient. In the separate dining room the space should be provided for a large table. Light and cross ventilation are important.

Living Room.—A small or medium-size living room is sufficient for the tenant house. The room should provide wall space for piano, book cases, and couch or davenport, and should have a southern exposure.

Bedrooms.—At least two small bedrooms should be included in the tenant house, and more, if extra help is to be boarded. The bedrooms should have closet space. Windows on two sides are desirable.

Bathroom.—A bathroom is essential in the tenant house as well as in the owner's house. The same septic tank may be used for sewage disposal from both houses. Guaranteed fixtures and a good installation are essential.



PLAN·L·SHAPE·TENANT·HOUSE·
FIG. 250.

Porches.—Porches to shade and protect the entrances and afford outside living rooms should be included in the plan. The porch should be 7 to 8 feet wide, and 12 to 20 feet long. A porch that is screened is much better than the open porch in the summer.

Basement.—A full basement for storage, utilities, vegetable storage and laundry is desirable. The cost of the basement room is less than for any other part of the house, and affords useful space.

Utilities.—The hot-air furnace, either with pipes or of the pipeless type is desirable for the tenant house. As the house is usually small, and on one floor, the hot-air plant is sufficient. As stated above, the same disposal plant may be used for the tenant house and the main house. If electric lights are

provided for the owner, the wiring may be carried to the tenant house at slight additional cost. Running water can usually be supplied from the same system that serves the owner's house.

Economy of Construction.—It is a bad mistake to attempt to lower the cost of the tenant house by the use of cheap or shoddy materials, or the omission of sanitary equipment. The cost may be reduced somewhat by the use of soft wood finish and trim, such as yellow pine or fir. The use of wall board in place of plaster will reduce the cost also. Small rooms, especially for the sleeping rooms, will not make the house less attractive. Additional rooms for hired men in the tenant house will make it possible to do away with help in the farm house, which is often to be desired. The extension of plumbing, water supply, and lights from the main house can be accomplished at low cost.

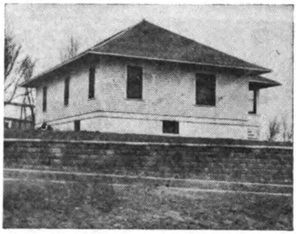


FIG. 251.—Tenant house in Iowa.

Bunk Rooms.—On many farms several men are kept the year around. It is desirable that they have quarters containing not only sleeping rooms, but also bath and recreation rooms. The use of separate buildings, or rooms over a garage or sales pavilion affords a convenient group of rooms. The rooms should be fitted with separate beds, bath, comfortable chairs, table, magazines, and phonograph.

Rooms in Main House.—In a majority of cases the farm help is housed in the farm home. If this is done, the men's rooms should be separate from the main part of the house, and a rear stairs is appreciated alike by the men and the owner. If the help is in the same house, the washroom, where the men may change clothing and bathe, is almost essential.

Careful planning of quarters, and a considerable investment for comfortable homes for the tenants will result in better, more contented help, and more efficient labor.

CHAPTER XXV

FARM HOME EQUIPMENT

THE development of farm home equipment has made it possible to place every modern convenience of the city house in the farm home. The labor-saving, convenient, health-producing features of running water, sewage disposal, plumbing, heating, and lighting should be provided for in every modern home. The tasks of the household may be lightened, and the workrooms of the house made light, pleasant, and comfortable.

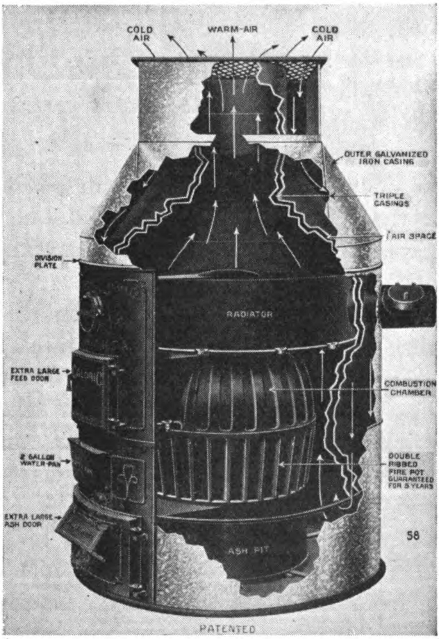


FIG. 252.—Sectional view of pipeless furnace.

The most recent developments in the line of home equipment are the pipeless furnace, mechanical refrigerating, and electric current for household motors and pumping. Much emphasis should be placed on the importance of complete equipment for the farm home.

Heating the Farm Home.—The warm air, steam, and hot-water heating systems are the common ones in use at the present time. Stoves and fireplaces for cooking and heating are being rapidly replaced by the efficient kitchen range, gas or oil stoves, and the basement heating plant.

Hot-air Furnace.—The warm-air furnace is the lowest in first cost, easy to install, and requires less attention than the other systems. It is flexible, and responds quickly when the fire is lighted. The disadvantage of the air furnace is the fact that there is likely to be some leakage of gases, imperfect distribution of heat in windy weather, and trouble from overheating.

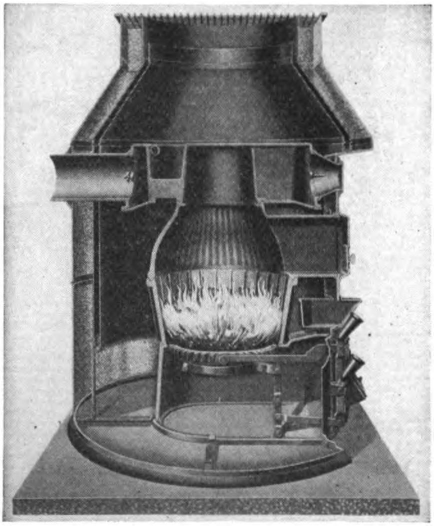


Fig. 253.—Section of pipeless furnace showing grate.

The furnace should be capable of heating the house to 70° F. in zero weather. A furnace may be purchased which is guaranteed to heat the house. Many architects recommend that a size larger furnace than absolutely necessary should be secured, as the larger one would require less forcing, and be more economical of fuel. Careful installation is necessary. The furnace should be placed as near the center of the house as possible, and preferably in a basement with at least 7 feet of headroom. A location away from the center should be toward the windward side of the house.

The two types of warm-air furnaces are the pipeless and the pipe furnace. The pipeless or one-pipe furnace is located in the basement under about the center of the house, and the

heated air passes directly from the jacket to a room or hall above. The heated air rises, and the colder air settles to the floor. The doors must be left open throughout the house to secure complete circulation. The furnace jacket is made in two parts, the heated air passing up through the center of the single register, and the cold air returning around the outside portion of the register. This type of furnace is low priced, economical, and easy to install in a new or old house.

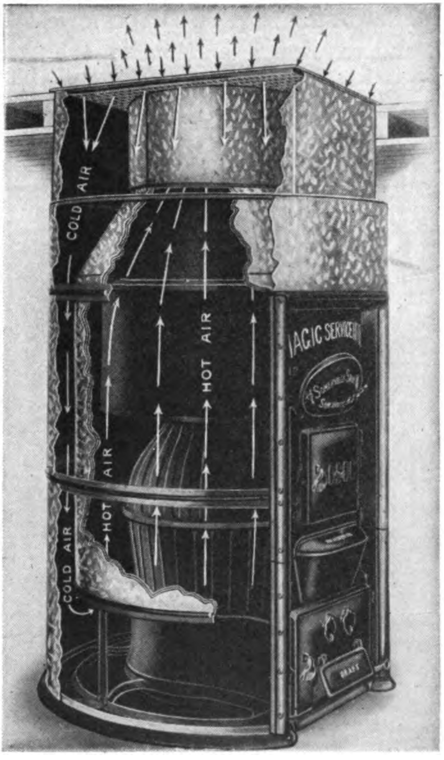


FIG. 254.—Showing air circulation in pipeless furnace.

The pipe furnace distributes the heated air to each room through thin, asbestos-covered metal pipes. The pipes from the furnace jacket are called leaders, and the vertical pipes are risers. The risers are rectangular in shape, and about 3½ by 14 inches in size, to pass through the average partition wall. The opening into the room is covered with a register, adjusted by a damper. The registers may be of the wall, base, or floor type. The base registers are usually preferred. The hot gases from the fire-box of the furnace pass through a heavy ring-shaped radiator to extract all possible heat from the fuel. Furnaces are made of cast

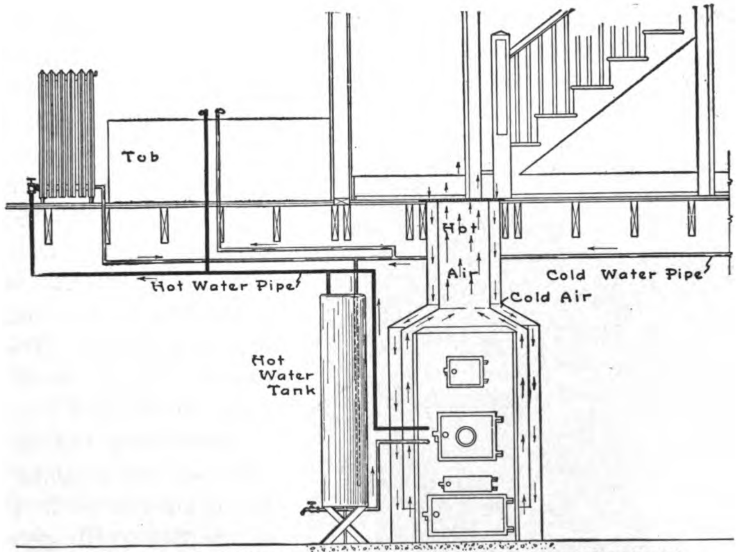


FIG. 255.—Illustrating method of heating bathroom with a water coil in a pipeless furnace.

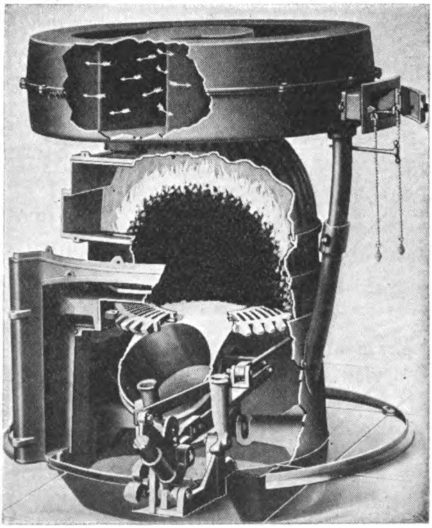


FIG. 256.—Section of a warm air furnace showing underfeed.

iron or steel. The steel is likely to warp and twist, due to the heat, and the cast iron may leak at the seams.

The cold air is taken from a room in the house, from several rooms, from the outside, or from a combination of inside and outside intakes. The cold-air supply from the rooms permits of reheating the air, and less fuel is used. The outside supply is always fresh, but cold air must be constantly warmed. A combination of the two methods of supply will give the best results. The outside supply should be taken from the protected side of the house, and provision made to regulate its volume.

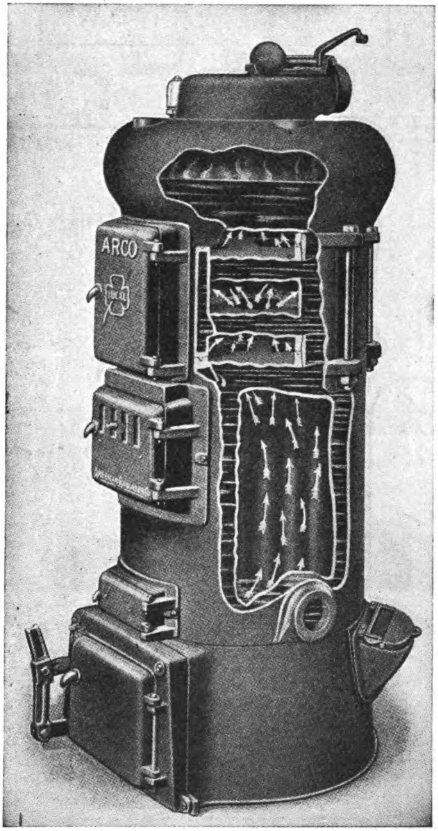


FIG. 257.—Upright steam boiler, sectional view.

Steam Heating.—Where steam is used as the heat-carrying medium, the system consists of a generator or b o i l e r, distributing pipes, and radiators. Steam heating may be classed as direct and indirect, and also as low- and high-pressure systems. The direct radiation supplies the heat from radiators in the room, and is the common system. Indirect radiation carries the heat through air, which is warmed by steam radiators, placed

in the basement, or under the floor. In the low-pressure system, the steam is forced to the radiators under light pressure, and the condensation returns to the boiler by gravity. In the high-pressure type, the pressure is high in the boiler, and reduced in the radiators, and the condensed moisture is returned by mechanical means.

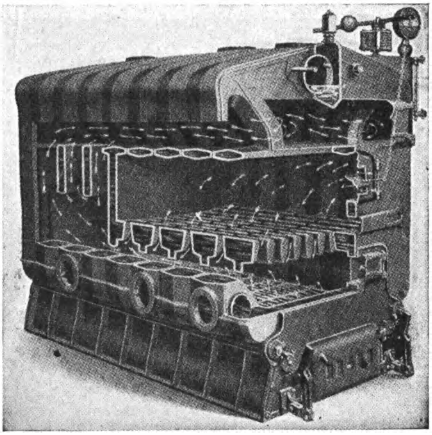


FIG. 258.—Horizontal steam boiler, sectional view.

Radiators.—The radiators for steam or hot water may be either floor radiators of cast-iron or wrought pipe, or cast-iron wall or ceiling radiators. The floor radiator is the most common. It is made in sections, and may be assembled to any desired size. The low radiators are more efficient, and are convenient to place under a window or in a bay; the high type is less efficient, but requires less floor space. The widths of radiators are single, two, three, or four column. To determine the size of radiator required, manufacturers have published handbooks, giving the square feet of radiating surface for each type of radiator, and the number of square feet required per room, under various conditions.

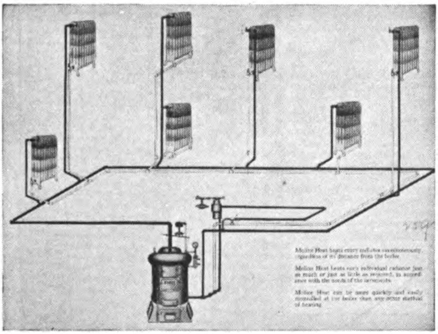


FIG. 259.—A steam heating system.

The purchaser should determine the amount of surface required from the handbooks. For living rooms it is usual to allow 1 square foot of radiator surface to 20 or 25 cubic feet, if there

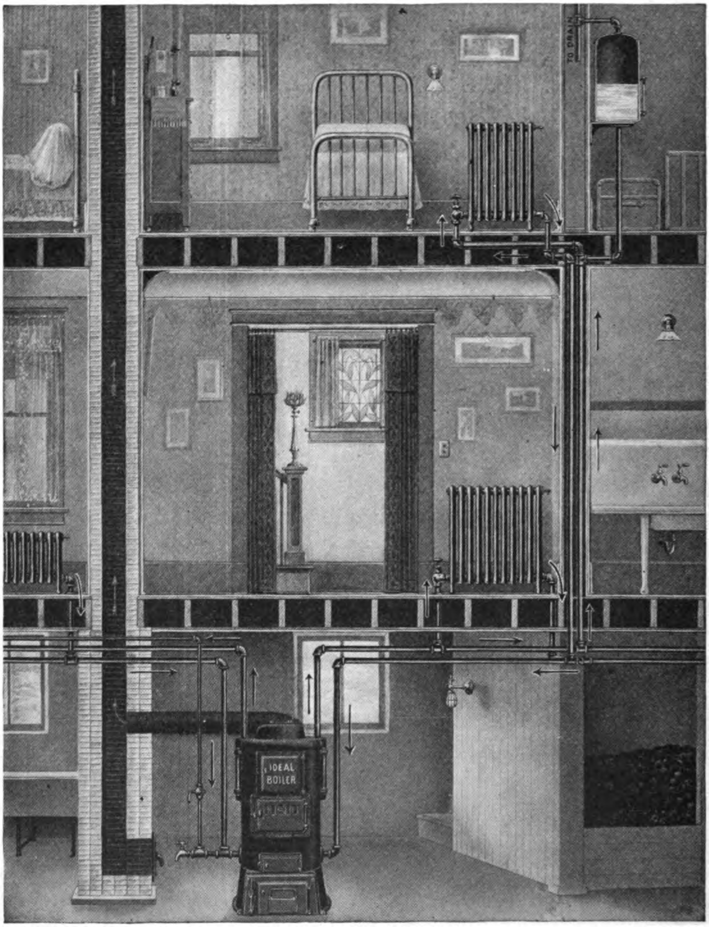


Fig. 260.—A hot-water heating plant.

is exposure on two or three sides. For sleeping rooms the radiation is lessened to 1 square foot for each 35 cubic feet in the room.

Piping Systems.—The two methods of piping are the single-pipe distribution and the two-pipe system. The one-pipe system, usually found in residence work, has one pipe leading from the furnace through the basement. From the pipe, risers are taken off to the various radiators, and the condensed steam is returned through the same pipe. In the two-pipe system, both a supply main and a return are used.

Each radiator has a valve to regulate or shut off the steam, and an air valve, to permit the escape of air when the radiator is filling.

Hot-water Heating.—The hot-water heating system is similar to the steam, so far as the installation is concerned. A two-pipe system is required, to carry the hot water supply, and return the cooler water to the boiler. The warm water is lighter, causing a circulation as soon as the water in the boiler is heated. The radiating surface for hot-water heat must be at least one-half larger than for steam, as the heating medium is at a lower temperature.

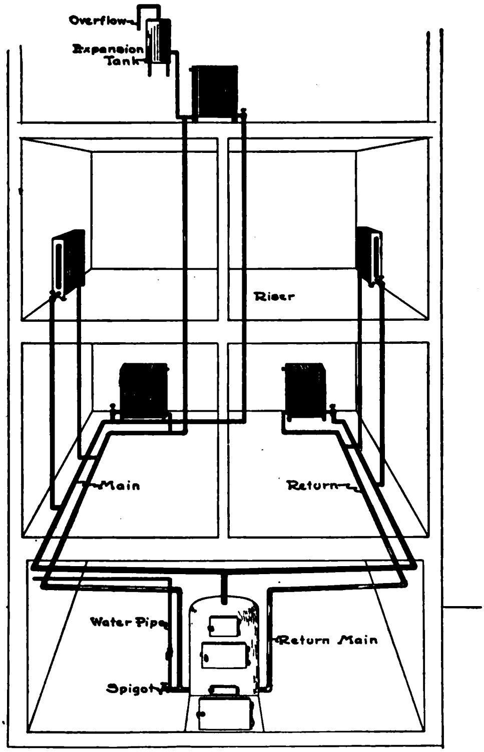


FIG. 261.—Two-pipe system for hot water.

Hot-water heating is more expensive to install than steam,

and requires attention to prevent freezing in cold weather. The system is flexible, and may be closely regulated, and affords a uniform heat. Over a period of fifteen years, the hot-water heating should prove the most economical.

Space does nor permit of a full discussion of heating systems. A study of each individual house is necessary to determine the best location of registers or radiators. The location of the boiler or furnace for the best distribution, the size for greatest efficiency, and the amount of attention required should be taken

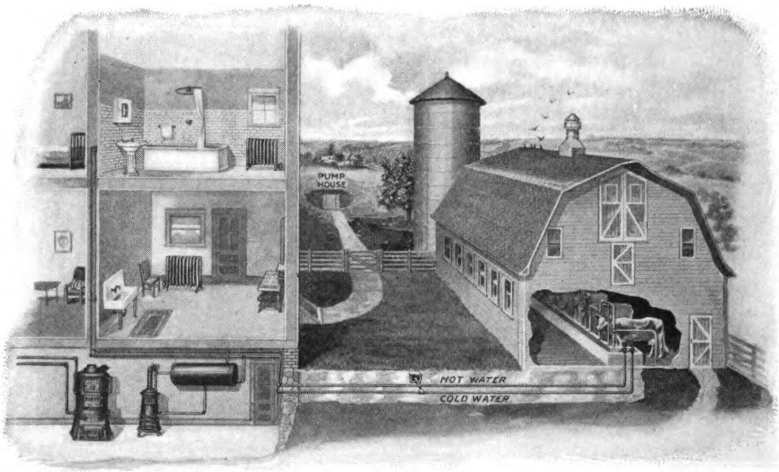


Fig. 262.—Showing method of transmitting hot water to barn or garage.

into account in selecting a system. Heat regulators, where possible, will make for more economy of fuel and a more even temperature. In the steam and hot-water systems the proper levels and slopes should be secured, to prevent water hammer and air traps.

Water Supply.—Running water is essential in the modern farm home, as the use of plumbing systems, sewage disposal, and the efficient laundry depend upon a constant water supply. Aside from the house supply, water should be available for the dairy barn, feeding yards, garage, and lawn and garden.

Once installed, a water system requires little attention, and the benefits are worth many times the cost.

Amount of Water Required.—It is generally assumed that each person in the household requires 25 gallons of water per day for all purposes. Each horse and cow needs 10 gallons, each hog 2 gallons, and each sheep 1 gallon. In addition some provision should be made for fire protection, garage work, and sprinkling.

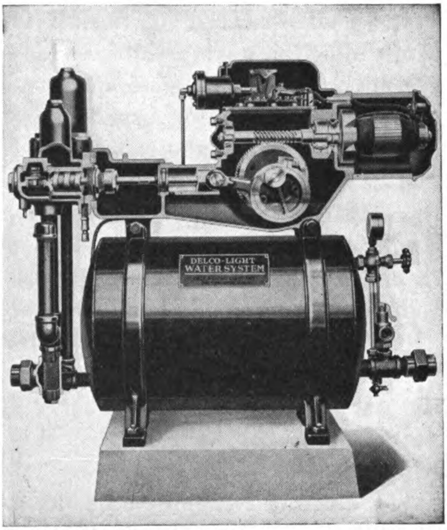


FIG. 263.—Sectional view of an electric-driven pump for shallow wells.

If windmill power is used, provision should be made for storing at least three days' supply. With gas engine or electric motor power, one day's supply is sufficient.

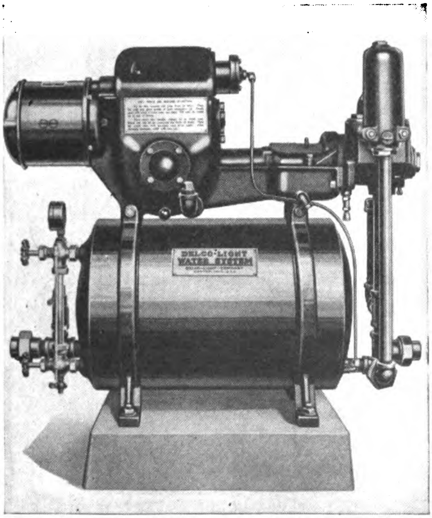


FIG. 264.—Assembly of the pump of Fig. 263.

Sources of Supply.—The usual sources of farm water supply are deep and shallow wells. Other sources in some localities are springs, streams, lakes, and cisterns. The purity of the supply is of greatest importance. If the water is drawn

from streams or lakes, care must be taken to prevent contamination through animal manures or household wastes. The water should be filtered, and frequent tests made to determine the purity. Cistern water, usually secured through the collection of rain water from the roof, is likely to contain vegetable or animal matter, which causes the water to become stagnant, and undesirable for drinking purposes. Springs usually afford a supply of pure, fresh water, and if the spring is protected from contamination, the supply is very desirable. Shallow wells include those in which the water stands not more than 22 feet below the surface, and deep wells include those of greater depth than 22 feet. The difference depends on whether the pump will draw the water by suction, 22 feet being the greatest practical depth at which a suction pump, or lift pump, will work.

Methods of Pumping.—The methods of securing the water supply depends on the source, whether springs, wells, or streams, and upon the elevation of the water as compared to the height of the tank or storage.

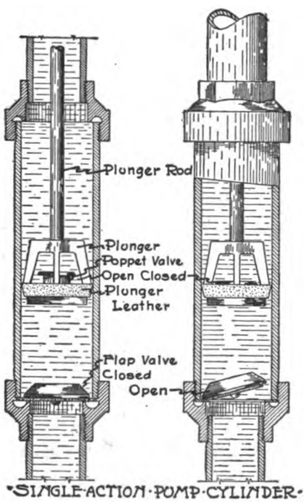


Fig. 265.—Details of single-action pump cylinder.

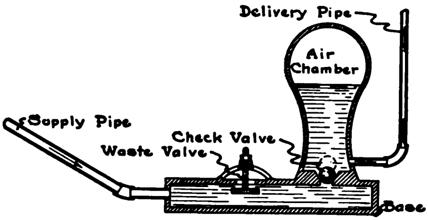
The lift pump will draw water by suction to a height of about 20 or 22 feet. It consists of a cylinder, and piston, with a valve arrangement, by which the water is lifted by forming a partial vacuum in the cylinder. The valves prevent the water from returning to the well.

Chain pumps consist of an endless chain, to which small cups are attached, and the water raised by dipping the cups into the water, and elevating them by a crank. This type of pump is used principally for cisterns or shallow wells.

Deep-well pumps are used where the water is to be raised more than 22 feet. The cylinder is placed within about 15 feet of the level of the water, and the water lifted to the pump stock by raising the water above the cylinder.

Force pumps, either lift or deep-well pumps, have the pump stock closed tight, in order that the water can be forced from the pump against pressure in a tank, or against the force of gravity to an elevation. Force pumps may be operated by engine power, electric power, by hand, or by windmills. They are in common use with the average water system on the farm.

Pneumatic pumps make use of a tank of compressed air, which is forced into the well through a piping system, to an arrangement in the well which forces the water to the taps by means of the compressed air. Space does not permit of a full discussion of this type of pump.



SECTION OF HYDRAULIC RAM

FIG. 266.

If the source of supply is a spring at a higher elevation than the house with a small basin at the spring, and a pipe line to a storage tank at the house, the water may be secured without pumping.

The hydraulic ram is a pump operated by water power. It is necessary to have a fall of a few feet from the spring or stream to the ram. A valve in the ram is opened automatically, and the water flows to the ram. When considerable velocity is reached by the water in the feed pipe, the waste valve closes. The momentum of the water in the feed pipe then forces a small amount of water into an air chamber, and up the discharge pipe. The ram is entirely automatic in action, and requires no attention other than starting, and an occasional inspection. The ram uses about $\frac{6}{7}$ of the water to gain momentum, and delivers about $\frac{1}{7}$ to the supply. Full

directions for installing are furnished with each ram. The conditions necessary for the ram are about 4 to 6 feet fall to the ram for momentum, a supply of water ranging from 3 to 10 gallons per minute, and a lift usually not exceeding 30 or 40 feet. The double-acting ram uses water from a stream for the motive power, and supplies the system with water from a spring.

Water Supply Systems.—The two general classes of water systems are the gravity or elevated-tank system and the pressure water system. In each type there are several different methods of installation and kinds of systems.

Gravity Systems.—The common gravity systems are the attic tank, storage cistern, or outside tank. Any of the several methods of pumping may be used.

Attic Tank System.—This is the simplest and the cheapest method of securing running water. A wooden or galvanized tank of 30 to 60 gallons capacity is placed in the attic of the house. A hand force pump is usually used to fill the tank, and it must be filled each day. A line of piping from the tank to the bath and kitchen fixtures completes the installation. The disadvantages of this system is the small storage, hand pumping, and possibility of freezing and leakage.

Fig. 267.—Cistern for water storage on earth mound.

Storage Cistern System.—If there is a hill or mound near the house, at an elevation such that a storage tank could be buried, and the bottom of the tank be above the highest tap, the cistern can be used with the water system. The tank should be built of concrete or brick, and of sufficient size for several days' supply. The buried tank prevents freezing, and keeps the water cool in the summer. The supply pipes are carried to the house underground, below the frost line.

Outside-tank System.—Most gravity water systems must make use of an elevated tank in the yards. Elevation is secured by placing the tank on a wood or steel tower, a masonry tower, an elevated area of ground, or on the top of the silo. The exposure is a disadvantage, on account of the danger from freezing, and sometimes on account of the appearance.

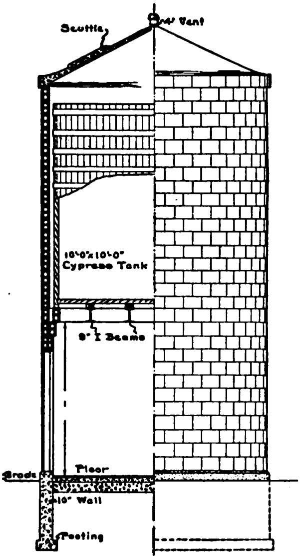


FIG. 268.—An elevated tank, enclosed.

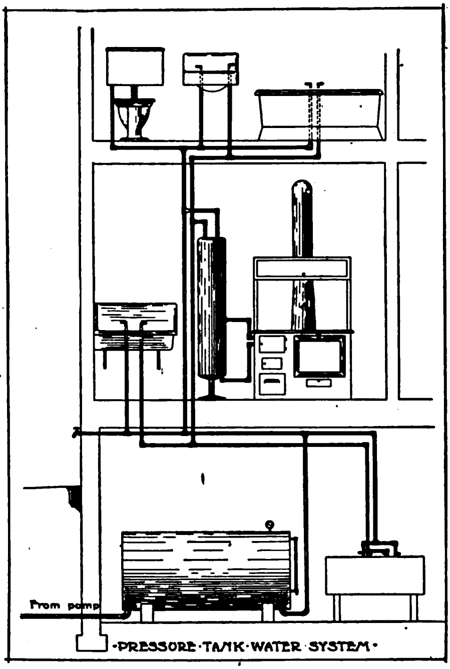


FIG. 269.—Hydro-pneumatic water supply system.

The outside tank may be constructed of concrete, tile, brick, or wood. Strong reinforcing is necessary, in the form of hoops or embedded rods in the masonry. The masonry tank requires waterproofing with commercial waterproofing compounds and plaster. A good type of gravity tank is a wood tank, made of 2-inch cypress, reinforced with hoops, and supported by I-beams, inside a silo-shaped tower. The

space under the tank in the tower affords a good cooling room, or small tool room. To protect the feed and supply pipes from freezing, the pipes should be thoroughly insulated with paraffin, dead-air spaces, and felt and paper coverings. If some water is pumped into the storage tank each day, the water from the well, which is warmer than that in the tank, will tend to retard freezing.

Pressure Water Systems.—The pressure systems consist of a steel tank, pressure pump or air compressor, power for pumping, and the piping system. The two commonly used systems are the hydro-pneumatic, which stores air and water in the same tank, and the pneumatic system, which stores compressed air only.

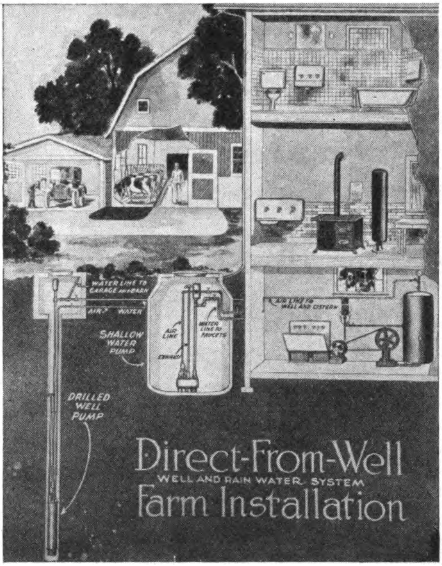


FIG. 270.—Pneumatic water supply system.

Hydro - pneumatic Systems.—In this system, the steel pressure tank is filled about three-quarters full of water, and one-quarter full of air. The compression of the air in the tank forces the water to the taps. The automatic electric-pump systems maintain the pressure between certain limits, without attention. With a gas engine, or hand pump, the power must be used to charge the tank when the pressure becomes low. The tank may be placed in the basement, or buried in the ground at the edge of the basement. The hydro-pneumatic systems may be secured for deep or shallow wells.

Pneumatic System.—This system consists of compressed

air alone, and the air pressure operates the air pump in the well. The system supplies fresh water automatically when the

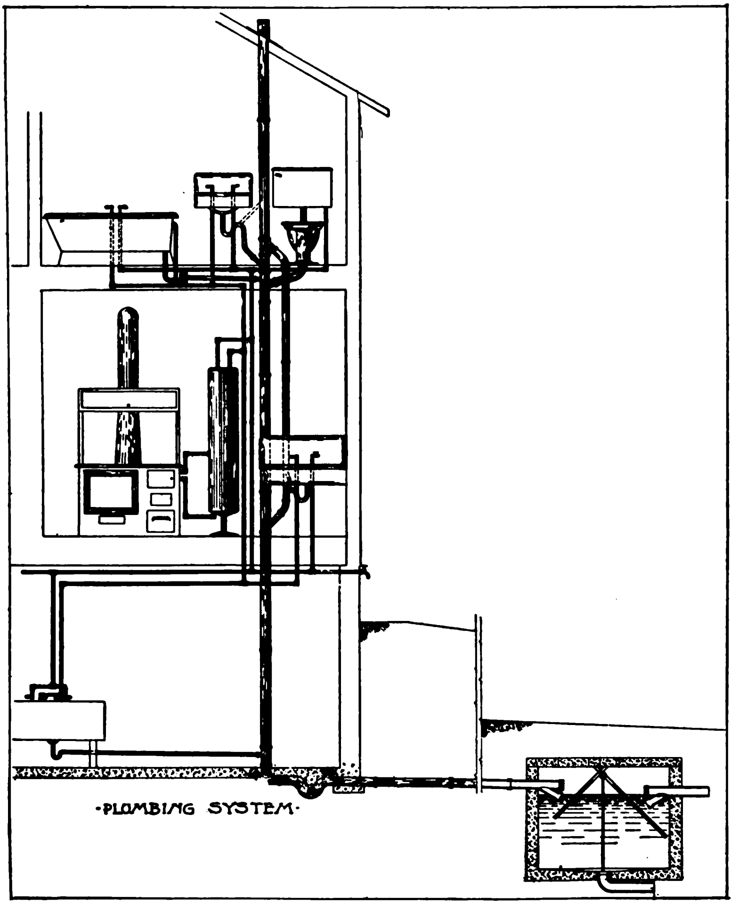
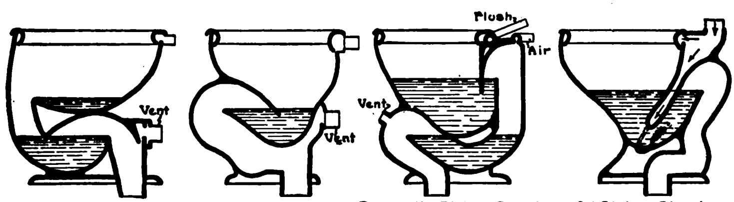


FIG. 271.—House plumbing fixtures and septic tank.

spigot is opened. The pneumatic water system is a more recent development than the other systems. It is proving satisfactory, however, and the higher cost is in many cases offset by the advantage of fresh water at all times.

Plumbing Fixtures.—The fixtures used in the bathroom, kitchen, and laundry are generally understood, and require only brief mention here.

The sewage system consists of a soil stack, made of heavy 4-inch cast-iron pipe, extending from the sewer or septic tank connection vertically to the roof of the house. The branch connections extend to each fixture, and must be given a slope to the main stack. The stack or soil pipe and branches also ventilate the sewage system. Traps or water seals are placed between each fixture and the stack, to prevent the escape of gases through into the rooms. "Back-venting" of each trap is desirable, although it is not always done. The back-venting consists of connecting the top of the trap with the soil stack,



·COMMON·TYPES·OF·WATER·CLOSETS·

FIG. 272.

to prevent unsealing by syphoning. Water-supply pipes are ½ or ¾-inch for the cold-water, and ½-inch for the hot-water pipes. The taps or cocks are brass, nickel plated. The sewer connections, stack, and fixtures should be carefully placed and made tight. In freezing weather, if the house is is to be left unheated for a time, an excellent method for preventing the bursting of pipes by freezing is to fill the traps with kerosene.

The plumbing fixtures include the bathtubs, closet, lavatory, kitchen sink, and laundry tubs. These fixtures should be of iron, with a guaranteed porcelain enamel coating, for the average installation. Bathtubs are about 30 inches wide, and 4½ to 6 feet long. The tub with one-piece base is preferable to the type with legs, as it is easier to keep clean, and

the space under the tub is tightly closed. The lavatory should be in one piece, with splash back, and large roll rim. The closet bowl should be of the syphon jet type, with low-down, porcelain tank. The frost-proof closet with the trap several feet below the surface is used in cases where heat is not available in the building. The wash-down closet and the high flush tank should not be used.

The kitchen sink is about 20 inches wide, by 24 to 30 inches high, with one or two drain boards. The sink should be of enameled iron, inside and out, and adjustable for height. The sink should be made with a splash back. Laundry tubs are made in pairs, or singly. They should have convenient drain, hose bibbs, and provision for attaching clothes wringer. They may be enameled, or of granite, soapstone, or slate.

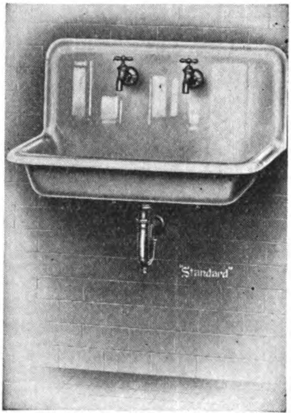


FIG. 273.—Common kitchen sink, bracket fastening.

A shower bath in connection with men's wash room or bathroom is a convenience that should be considered.

All lavatories, baths, sinks and laundry tubs should be supplied with both hot and cold water. The hot-water supply is secured by attaching a hot-water tank to a supply pipe, with a heating coil to the furnace, range, or separate heater. A hot-water tank of 30 gallons capacity will be sufficient for this purpose.

Sewage Disposal.—The disposal of the wastes from the bath, kitchen, and laundry fixtures is one of the most important problems of sanitation on the farm. Formerly, the wastes were often emptied into a cesspool, or dry cistern, from which the liquids seeped away, and the solid matter was cleaned periodically. This was a disagreeable task, and the seepage from the cesspool endangered the water supply. In some

cases the sewage is dumped directly into a small stream, but this method is objectionable, because the raw sewage attracts rodents and flies, and the sewage may contaminate the water supply on another farm. The outdoor privy, and the practice of emptying wastes from the kitchen and laundry into the yard are insanitary, dangerous, inconvenient, and unhealthful.

The modern, practical, and the only satisfactory way to

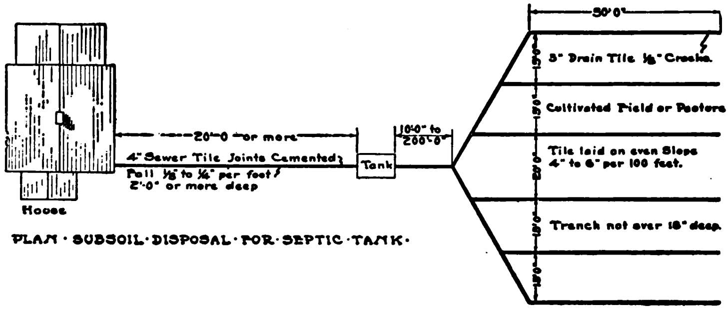


FIG. 274.—Plan of a sewage disposal plant.

dispose of the sewage from the farm house is by means of the septic tank.

Septic-tank Action.—In the septic tank, the sewage from the house is carried to a settling chamber, large enough to hold the sewage for about twenty-four to forty-eight hours. The settling chamber is dark and tight, except for the outlet pipe and vent. The sewage, when it enters the tank, is attacked by bacteria, which feed on the sewage, and thrive under the conditions in the tank. The bacteria form a scum over the surface of the liquid, which is partially airtight. The bacterial action of these "anaërobic" bacteria changes the solids in the sewage to liquids and gases, except for a small amount of sludge or solid matter.

From the settling tank the liquid flows to a dosing chamber, or to an outlet, depending upon the type of disposal plant. From the outlet the liquids are carried to a filter, or sand

bed, for further action. When the sewage leaves the settling chamber little purification has been done. The liquid is carried through a line of drain tile, and dumped over the surface of the ground, where it filters into the soil, or evaporates, and the sunlight and air complete the purification process. A better method is to empty the drainage from the tank into a trench, through the joints in the tile, and allow the liquid to filter through about 18 inches of sand and gravel to another line of tile in the bottom of the trench. A still more complete

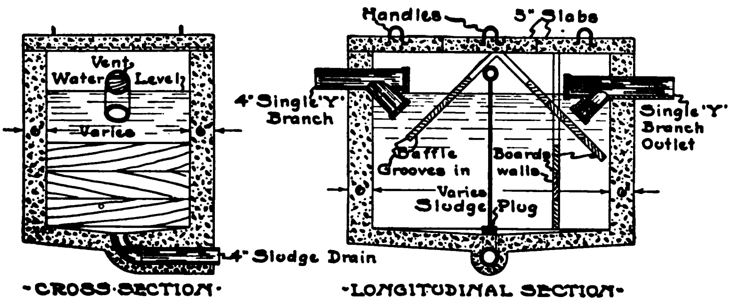


FIG. 275.—Single-chamber septic tank.

method of purification is to carry the drainage to a sand bed, about 20 feet square, and allow the liquid to settle through 18 inches of sand over the bed. Either the sand bed or trench should always be used, to avoid possible danger of contamination or disease spreading. The filter takes out suspended particles of solid matter, and further purifies the liquid waste by the action of "aërobic" bacteria, which thrive in air and sunlight.

Types of Septic Tanks.—There are several types of septic tanks in use, made of various materials and in different shapes. There are several commercial tanks on the market. This discussion will be confined to the two most common forms, both of which can be made on the farm.

The Single-chamber Tank.—The single-chamber tank receives the sewage into the one chamber, and there the septic

action is completed. The discharge is continuous, or there is a discharge each time more liquid enters the tank from the house. The continuous overflow does not allow the filter beds to aërate properly, and they become inefficient in time. This tank is used for a low-cost system, or where the ground is so flat that not enough fall can be secured for the double-chamber tank.

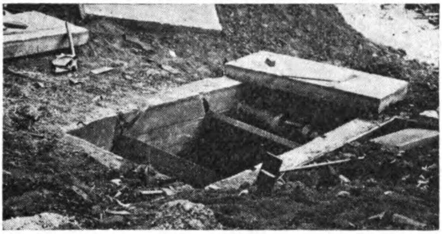


FIG. 276.—View of single-chamber septic tank before covering.

Double-chamber Tank.—This type of septic tank has a settling chamber which receives the sewage, and a dosing chamber, with a syphon. The discharge into the dosing chamber is continuous, and the chamber is large enough to hold the liquid for twelve to eighteen hours. When it is full, the automatic syphon dumps the liquid out into the drain, and spreads it over the ground or on the filter bed.

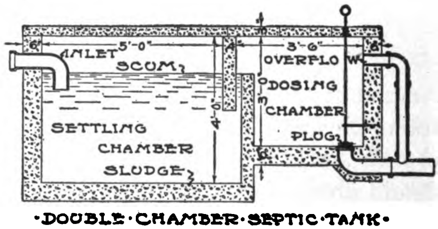


FIG. 277.—Section of a two-chamber septic tank.

Size and Construction.—The size of the septic tank of either type should be sufficient to hold the sewage for twenty-four hours or longer, to allow complete bacterial action, but not long enough for decay to begin. For the average farm family a tank $3\frac{1}{2}$ feet wide, 4 feet deep, and 5 to 6 feet long will be correct. This cares for the sewage for a day, and permits some space at the top of the tank for the scum to form. In the double tank the dosing chamber should be about half the size of the settling chamber.

The pipe from the house should be a 4-inch, bell-mouthed, glazed sewer tile, with cemented joints. The fall should be from $\frac{1}{8}$ to not more than $\frac{1}{4}$ inch per foot. The best construction for the tank is concrete, of a 1:2:4 mixture, with walls 6 inches thick, the top being a reinforced slab of concrete, with iron rings inserted for lifting. Heavy-mesh fence wire will afford sufficient reinforcing. The inlet and outlet pipes should be put in place when the concrete is poured. A baffle box is placed at the entrance, to break the flow of the sewage and avoid disturbing the contents of the tank, and a vent is made in the top of the tank. Usually the septic tank should be placed 50 feet or more from the house, at a depth just sufficient to place the top of the tank slightly below the surface. The syphon may be purchased from a commercial company ready to install.

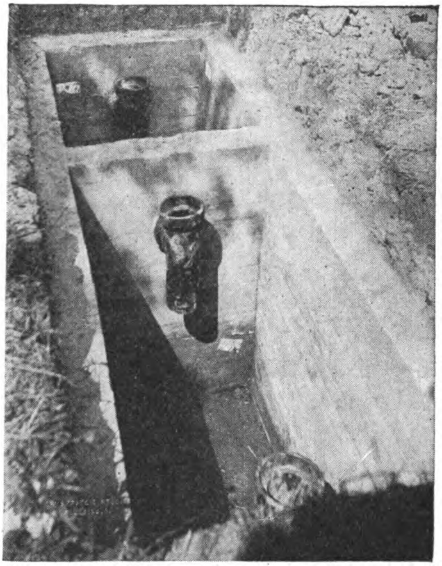


FIG. 278.—Two-chamber septic tank.

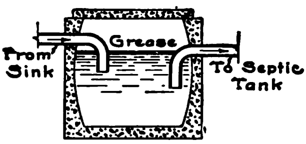


FIG. 279.

Care of Tank.—The septic tank should be cleaned out every two or three years, and frequent attention should be given to make sure that it is working properly. Grease in quantity will prevent proper action, and a grease trap from the kitchen drain may be necessary.

Farm Lighting.—Modern methods of lighting are fast

being installed in the farm homes. Natural lighting is best, and ample window space and correct location of windows is important. The artificial lighting for the farm has developed from the pine torch and tallow candle to the kerosene lamp. At present the oil lamp is being replaced by the modern lighting system. Kerosene mantles, kerosene and gasoline gas systems, and patented lamps using various fuels are on the market, and some of them are low in cost and reasonably efficient.

For modern lighting for the farm home, however, only three systems are important enough to warrant a discussion here. They are the Blaugas, acetylene, and electric.

Blaugas.—This gas is an oil gas, and its manufacture and distribution is controlled by an Eastern firm. Gas plants and distribution stations are located at convenient points over the country. The gas is sold in steel tubes, each containing about 20 pounds of the gas, which is compressed to liquid form. The system consists of a reducing valve, expansion tank, regulating valves, and the necessary piping. Blaugas is inexpensive for the installation, the complete plant costing around $150, with the pipe and fittings extra. The gas is about the same in action as city gas, except for a much greater heating value per cubic foot. The system is highly recommended by users both for cooking and lighting. The chief difficulty with Blaugas is the necessity for returning the tubes by freight for refilling.

Acetylene.—The addition of calcium carbide to water produces a hydro-carbon gas called acetylene. The gas burns with a white, intense light that is the nearest approach to natural light. The system consists of a generator, tank, valves, and the piping system. The correct type of generator is the one in which the carbide is dropped into water by a clock-work arrangement. The generator is now furnished for installation in the house or out of doors. The outside installation is the safer.

Acetylene has a rather wide explosive range, but should be safe, if handled according to directions and the installation

made in accordance with the Underwriter's rules. The gas has an unpleasant odor, by which leaks may be detected. Open flames should not be allowed near the generator, and filling should be done in the daytime. Calcium carbide is a commercial product which may be secured through widely distributed dealers. The cost is more than for the Blaugas, but somewhat lower in price than the electric.

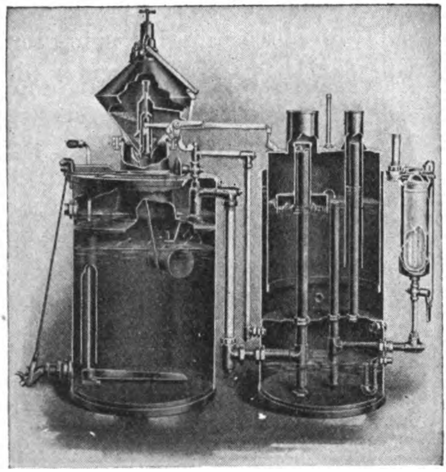


FIG. 280.—Sectional view of acetylene generator and tank.

Electric Lighting.—The value of electricity and its many uses are well known. The transmission or high-tension line affords a valuable source of current, if available. Many communities are now supplied by the central plant and the cross-country line. With 110 volts available,

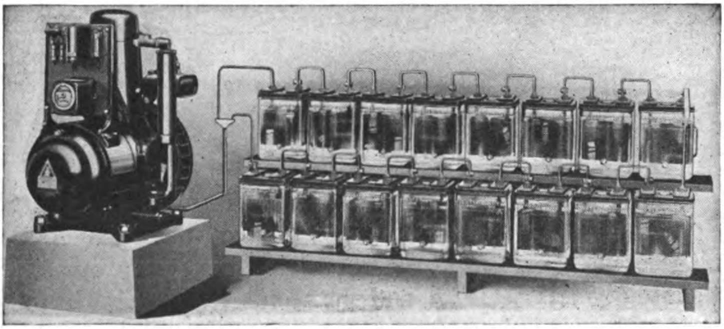


FIG. 281.—An electric lighting plant.

the farm may be supplied with all power necessary for the farm work, at a low cost and in a convenient manner.

The isolated electric light and power plant is a development of the past few years, and the distribution has been very rapid. Besides furnishing lights for the house and barn, the small plant has sufficient power for flatirons and motors up to $\frac{1}{4}$ horse-power.

Parts of Small Plant.—The individual light and power plant consists of engine, generator, switchboard or control, and the storage battery.

Engine.—The engine size depends on the size of the plant. The usual size ranges from 1 to 4 horse-power. The engine may be of the two- or the four-cycle type, either air or water cooled. The light-plant engine should be steady, smooth running, and simple in construction.

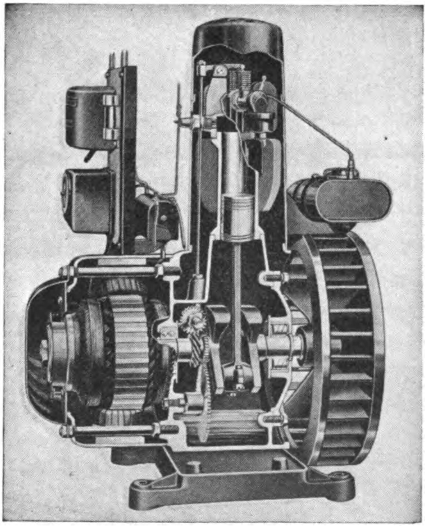


FIG. 282.—A sectional view of engine and generator of the plant shown in Fig. 281.

Generator. — The generator is rated in watts capacity, ranging from 750, or practically 1 electrical horse-power, to 2000 watts. The generator is of the direct-current type.

Switchboard.—The control board contains the fuse plugs, current-measuring devices, and the starting button. In the automatic outfit, the control is a part of the switchboard apparatus. The automatic plants start and stop when necessary, and throw out completely when the plant is overloaded.

Battery.—The usual farm plant is 32 volts, with 16 cells

in the battery. The battery is rated in ampere hours capacity, based on the normal rate of discharge for eight hours. For example, the 80-ampere hour battery will furnish 10 amperes of current for eight hours at 32 volts, or 320 watts for eight hours without recharging. For heating elements, or motors requiring more than the normal output of the battery, the engine should be run, and the current taken direct from the generator. For the average installation not less than a 160-ampere hour battery should be used.

Current Used.—The amount of current depends upon the number and kind of fixtures. The following list shows the amount of current consumed by the average fixtures. Sufficient size of plant and battery should be secured so the plant will need charging only each three or four days.

Fixture	Current, in Amperes at 32 Volts
20-watt lamp	.625
40-watt lamp	1.25
Sewing machine motor	1.5
Vacuum cleaner	5.5
¼ H.P. motor	12.0
Toaster	15 0
6-pound iron	18.0

It will be seen from the above table that the use of heating devices places a heavy load on the battery, and should be operated only when the engine is running.

General Considerations.—A waterfall as a source of current is possible in many parts of the country. Where possible, a 110-volt generator should be used, of large capacity, as the low cost of power will make it economical for all farm power work.

As a rule, the plant should be of ample capacity, possibly larger than the estimated requirements show, as there will

be a tendency to use more lights and motors, once the plant is installed.

A battery capacity of more than 100 ampere hours is preferable to the smaller batteries, if any motors or heating

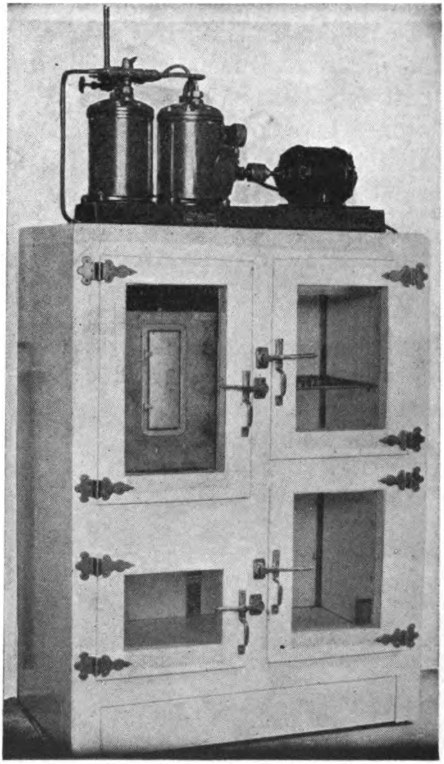


FIG. 283.—A mechanical refrigerating plant for residence.

elements are to be used. It is possible to secure direct-connected and belted-engine outfits. The belted plant makes it possible to remove the engine for other work, but the present tendency is toward the direct-connected plant, with the engine used for no other purpose.

It is necessary to use heavy wires with the low-voltage plant. No. 8 feed wires, and No. 12 house wires should be used in preference to smaller sizes.

A separate circuit of wires in the house for the motors and iron is both desirable and convenient.

Mechanical Refrigeration.—The small household refrigerator operated with electric power and a small motor have come into recent use. The refrigerators will automatically maintain an even, dry cold, and freeze small blocks of ice. Manufacturers are working toward the development of the mechanical refrigerator for use with the small electric plant, but as yet none is available for the 32-volt farm plant.

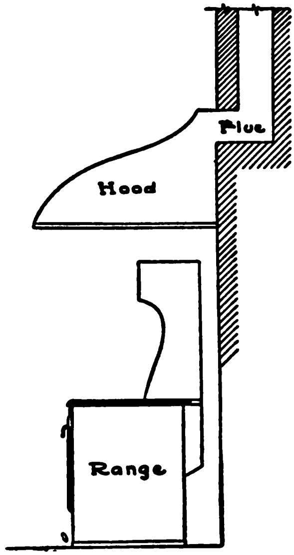


FIG. 284.—Range hood for ventilation.

Kitchen Ventilation.—A metal hood over the kitchen range will ventilate the kitchen, and remove the steam, gas, and heat in summer. The use of the range hood will aid in making the kitchen a cool, pleasant workroom.

CHAPTER XXVI

FARMSTEAD PLANNING

THE early development of the farmstead group was carried on under much different conditions than exist to-day. On most farms the buildings were erected over a long period of years and the correct relation of one building to another could not well be maintained. Protection from Indians and wild animals often compelled the location with reference to nearness to neighbors. Water supply, wet lands, or timber in many cases determined the location without reference to other factors.

At the present time the need for protection against enemies is not usually a factor in locating the buildings. The automobile, telephone, and rural mail delivery have lessened the isolation felt by the farmer of fifty years ago. Shortage of labor, high-priced land, permanent building materials, and architectural considerations have each had some influence on the problem of farmstead location.

Advantages of Good Grouping.—The advantages of a good farmstead plan and arrangement of the buildings are almost self-evident. The more important are efficiency, appearance, and sanitation.

Efficiency is gained in a grouping of the buildings to save the most possible steps in doing the farm work, both on the farm and in the necessary work of marketing, and in community activities. Duplication of steps should be avoided. Gates and fences should be arranged to afford the best plan of the grounds, and to interfere least with the work. Distance to fields and to market have an effect on the efficiency of the worker.

More consideration should be given to appearance than has been given in the past. Usually the efficient plan is also susceptible of treatment, by planting and arrangement, to produce the best appearance. Appearance has an influence on the selling value of the farm, upon the pleasure derived by

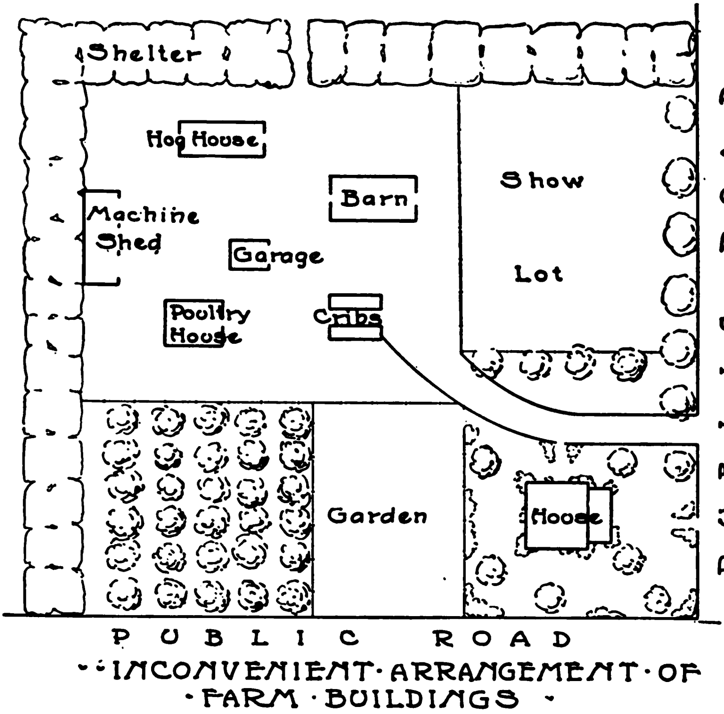


Fig. 285.

the family; furthermore a farmer's standing in the community may be affected by the appearance of the building group.

Sanitation is promoted by the lay of the land, or the contour; by drainage; by the nature of the soil; and by the relation of the stock barns to the dwelling within the group.

General Problems of Arrangement.—Freak arrangements should be avoided. The frequent desire to place the buildings in a straight line or on a curve should be suppressed.

The buildings should occupy positions of graded importance in the group, according to the use, appearance, and plan. The house should usually be given the most prominent position, while the smaller unimportant buildings should be subdued, and possibly hidden by plantings.

Existing farmstead groups that are unsatisfactory may gradually be changed into a good arrangement, even though the present plan is quite firmly established. Gardens, feed lots, and fences may be changed with very little labor, and poultry houses and smaller structures moved. Plantings will often aid the appearance of the group with little cost. With a definite plan in mind, permanent structures may be placed in their correct position as it becomes necessary to replace the old ones.

Every problem of farmstead plan is a subject for individual study, and rarely can a good plan be secured by following general plans in detail without changing to fit the conditions.

Best results in planning the building group will be secured by keeping in mind the principles of farmstead location, in connection with a careful study of the farm and building site. The type of farming and the section of the country will have an effect on the location also. It must be remembered that certain points are more important than others. For instance, the water supply is more vital than the type of soil on which the buildings are to be placed.

Factors Affecting Location.—There are three groups of factors or conditions which affect the location of the farmstead and buildings. They are the outside factors, natural conditions, and the relation of the buildings within the group.

Outside Factors of Location

Transportation.—The farmstead should be placed on the best highway available. Convenience to telephone, rural delivery, and motor truck or wagon routes is important. Electric lines are sometimes available if the buildings are close

to a good highway. Ease of access to the buildings is important when many products are sold from the farm through the medium of annual auction sales. Since much of the farm produce is hauled to market, good roads lessen the cost of the products. On some farms the electric car line is a benefit to the particular system of farming.

Social Factors.—The farm family is left much to itself, and requires social conditions that will relieve the monotony of the living for many people. In general, the farmstead should be placed near the road, rather than in the center of the farm.

Schools, churches and neighbors are essential to the social life of the farm, and nearness to these features has an important influence on the location of the farmstead. The development of the co-operative associations and country communities shows the need for consideration of conditions outside of the farm itself when locating the building group.

Markets are essential for farming, and nearness to market will often determine whether the crop shows a profit or a loss. It is sometimes possible to reduce the distance to market by more than a mile in every trip by careful selection of the building site.

Natural Conditions

Water Supply.—The existence of springs, flowing wells, or streams of pure water often determine the location of the buildings without reference to other factors. The possibility of water pressure, location of storage tanks, or pumping by means of the hydraulic ram should be considered. Since deep wells are available at any point on the farm, this factor will not determine the location.

Contours.—The lay of the land, and the slopes around the farmstead should be considered. Drainage is essential, and if the ground is not naturally well drained, it is necessary to provide tile lines and ditches. The slope of the ground should carry the surface water away from the buildings. The barnyard should not be drained toward the house, or toward a well. Low swampy spots near a building site are undesirable.

Buildings located in a valley are likely to be improperly drained, and the sunlight is not effective throughout the entire day. Located on a hill, the buildings may be exposed to the winter winds. Steep slopes require terraces, and a good layout of the buildings is often difficult.

Usually a slightly rolling, south, or southeast slope is to be preferred as a building location. The house should be higher than the surrounding buildings.

Nature of Soil.—Since the buildings require space that might otherwise be used for production, they may well be located on the poorest ground, and because of the better drainage and sanitation, they should be located on a light porous soil rather than a heavy clay. Unless other factors are equal, no especial attempt should ever be made to place the buildings on the unproductive soil.

Protection.—Natural features of protection should be utilized to shelter the buildings. A timbered area or hill, in the direction of the prevailing winds in winter, affords an excellent windbreak.

Relation of Buildings in the Group

From the standpoint of efficiency and appearance, the best results can be secured by careful attention to the location of the buildings making up the farmstead. The buildings must be located individually, for their special requirements, and with relation to surrounding buildings.

Types of Farmsteads.—There are two types of farmsteads in use, known as the concentrated and the distributed groups.

The concentrated group includes all of the buildings under one roof, or all of the buildings connected, that is the structures are connected to form a sheltered yard or court. The advantage of this grouping is in economy of construction, and the convenience of handling the work. The disadvantages are that the fire risk is great, animal odors are objectionable in the house, and the yard space for the stock is restricted. Few farmsteads of the concentrated type are now used in this country.

The distributed system of farmstead location is the type almost entirely used at the present time. The buildings are far enough apart to avoid stable odors in the house. Fire risk is decreased, and usually better sanitary conditions prevail. The buildings should, however, be located closely enough together to reduce to a minimum the labor required.

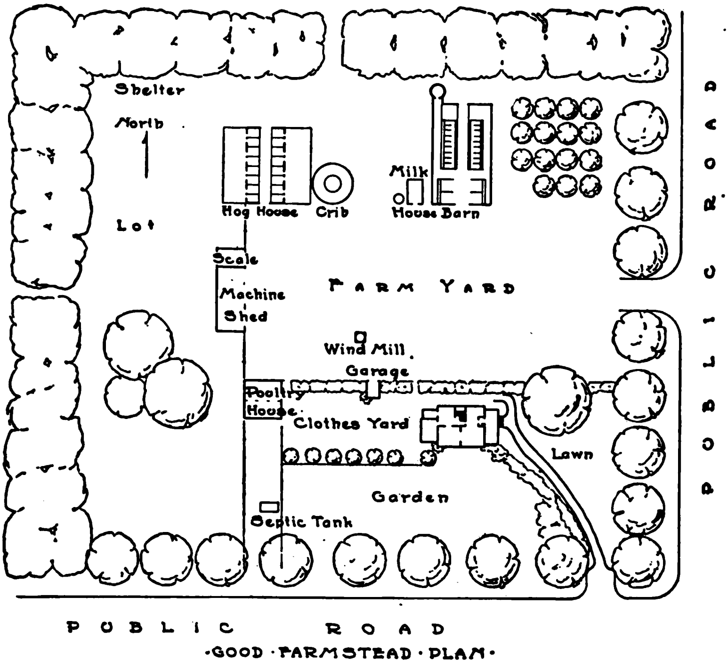


Fig. 286.

The exact arrangement will, of course, depend upon the individual problem. The best farmsteads, however, usually arrange the buildings around a rectangle or court, somewhat to the rear of the house, and on one side. The house is the most prominent building, and the main barn is next in importance. The object in the grouping is to plan the buildings so they may all be entered without passing

through gates. The court should afford a service yard, or drive, and the feed lots will be located to the rear of the barns and away from the house.

Aside from the main grouping of buildings, other buildings should be grouped near each other, according to their uses. The tool shed, machine shelter, and garage should be near together because of a similarity of uses. The corn crib, hog house, and cattle-feeding shed should be near together for convenience in feeding.

House.—The house should be nearer to the highway than

FIG. 287.—A group of buildings about barn.

the other buildings, the arrangement and planting being made with the object of showing the house to the best advantage. The barn, public road, and a part of the fields should be visible from the house. The best distance from the road to the house is between 100 and 150 feet. This location affords a reasonably large lawn, and places the house away from the dust of the road. The facing of the house is usually made with respect to the road, and an east or south front is usually preferred. The lawn in front of the house should be fenced to keep poultry and small animals away.

Barns.—The stock barns should be set with the long axis to the north and south, for best lighting, and to form a

protection for a sheltered yard. The barn should be 150 to 200 feet from the house, and if possible, in the direction away from the prevailing summer winds. The kind of stock, the necessary number of yards, and the type of farming will have some effect on the location.

Hog House.—The hog house should be farther from the house than the barns, on account of the odors, but near the cribs, for ease in feeding, and to be easy of access by men and teams. The location for sunlight has already been considered.

Grain Storage.—The corn crib and granary may be located for convenience in filling from the fields, and convenient for the sheller and grinder. For feeding work the grain buildings should be near the feeding lots and hog house. There must be a driveway leading to and from the building, and no fences should interfere with the operations. A location between the hog house and barns is desirable.

Machine Shelters.—The principal factor in locating the machinery buildings is the convenience in getting the equipment in and out of the shelter. These buildings may be nearer to the house than the barns, while the garage for the car should be near the house.

Other Buildings.—The poultry house may be nearer to the dwelling than the other buildings, but should be kept away from the barns and grain-storage building. It should face the south, and be located on porous, well-drained soil. The ice house, milk house, and pump house may well be located between the house and the dairy barn. The other small buildings should not be so located as to interfere with the appearance of the group, but the necessary ones should have as careful planning of location as the more important structures. As a rule, the fewer miscellaneous buildings there are, the better for the farmstead.

Planting.—It is not the purpose of this text to discuss the planting, which is the function of the landscape gardener and architect. Only a few general suggestions are necessary here. There should be an evergreen windbreak to the north and west of the buildings in most parts of the country. The

south side of the group should be nearly free from trees, in order to take advantages of the summer winds. Natural timber growth is sometimes utilized as a windbreak.

FIG. 288.—A building group without trees.

Fruit trees, shade trees and flowering plants and shrubs are desirable additions to every farmstead. The farm home should have an orchard and garden.

Most of the planting should be along the sides and back

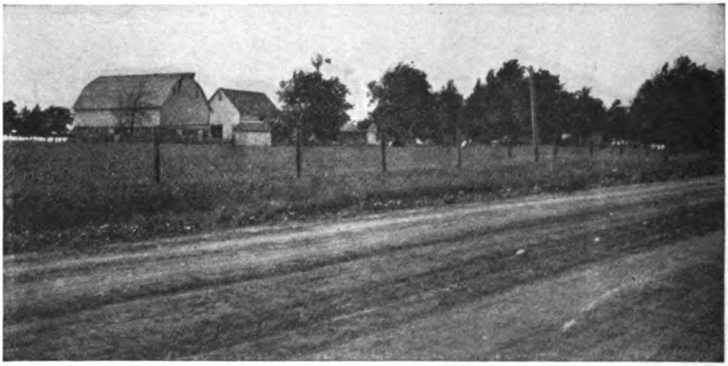


FIG. 289.—A building group among trees.

of the lawn, rather than in front of the house. Shrubs and hedges are utilized to hide undesirable views. Planting in irregular outline is usually preferable to straight rows. All planting is for the purpose of beauty, and to blend the buildings

with the natural surroundings. Before permanent plantings are made, a specialist should be consulted.

Farm Layout.—The layout of the fields is a problem of farm management. Square or rectangular fields require the least fencing. Irregular fields are to be avoided, because of the time and trouble required properly to cultivate them. For power farming the large field is the most economical. Pastures should be near the barns, to avoid lanes, while the farther fields may be used for hay, cultivated crops, or for

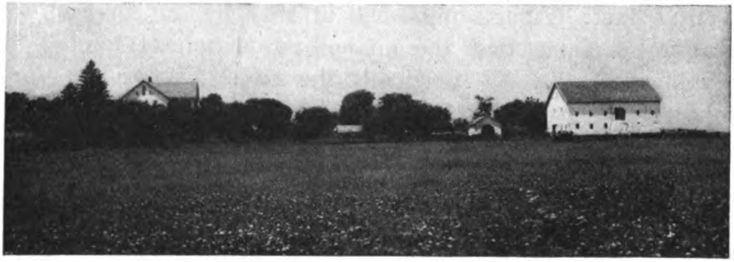


Fig. 290.—A farmstead with trees.

grazing feeding stock. There should be no open ditches in the center of a field, if it is possible to avoid it.

The garden should be near the house, and not closer to the road than the house. The use of a show pasture in front, or to the side of the farmstead will serve the double purpose of displaying the best animals, and providing a clean permanent pasture near the house, instead of cultivated, dusty fields.

The farmstead for the farm of 160 to 240 acres will require about 3 to 4 acres for the buildings, drives, and planting. Plans calling for 5 and 6 acres of space are rather more elaborate than is necessary for the average farm.

CHAPTER XXVII

WOOD AS A BUILDING MATERIAL

Wood has always been the most widely used building material and it is probable that for some time it will continue to rank first. Figures published in 1917 by the Division of Forestry indicate that the annual production of lumber is 40 billion board feet. Originally the supply of standing timber was well distributed over the country, and the forests were thought to be vast enough to provide sufficient lumber for all time. The per capita consumption, however, has increased at the rate of 20 to 25 per cent each decade since 1860, and due also to the great waste in forestry methods, the supply has been depleted rapidly. Government estimates place the amount of standing timber large enough for cutting at 2800 billion feet, which at the present rate of cutting would last something over sixty years. New growth and forestry practices will doubtless conserve the supply.

The logging interests have followed the areas of heaviest supply from Northeast to the South and West. In 1850 the Northeastern States produced 54 per cent of the total lumber in the United States. The Lake States supplied the largest amount in 1890, and in 1914 the Southern States supplied nearly one-half the total.

The cost of lumber has been increased by the greater cost of labor, transportation, and manufacturing involved in securing the supply from remote districts and from a decreasing supply.

Advantages and Disadvantages of Wood.—The advantages which have enabled wood to hold first place as a building material are low cost, wide distribution, ease of working, light weight, appearance and adaptability.

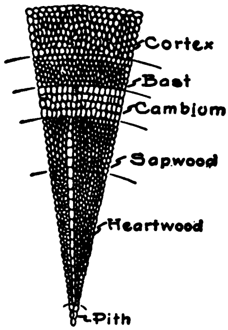
The disadvantages of wood construction, as compared to other building materials are increasing cost, decreasing supply, inflammability, tendency to decay and the fact it is unsanitary for many uses.

Classification of Woods.—Woods are classified and known by terms which distinguish certain characteristics. The classifications which apply to structural timber are considered here.

Broad-leaved and Conifers.—The broad-leaved trees are deciduous, shedding their leaves each fall. The needle-leaf or cone bearing trees are called conifers, and are termed, also, the evergreens.

Hardwoods and Softwoods.—The evergreens or conifers yield the softwoods and the broad-leaved trees furnish the hardwoods of commerce. As a matter of fact the yellow pine, classed as a softwood, is harder in structure than the bass wood, which is a broad-leaf tree.

Endogenous and Exogenous.—This classification refers to the manner of growth. Endogenous trees are of the type of the bamboo, or palm, which has a hard shell, and a hollow or pithy interior. The trees mostly used for structural purposes are the exogenous, or outward-growing trees.



·STRUCTURE·OF·WOOD·

Fig. 291.

Sapwood and Heartwood.—As the tree increases in size the central part becomes hard, due to drying out and because of the compression of the outer layers of growth. This part is called the heartwood, and is prized as a building material on account of its strength and firmness. The layer between the heartwood and the bark is called the sapwood. This is a light, sappy, porous wood, not so valuable as the heart. A small pith is found at the center of some varieties, but is unimportant. The outer bark is of no value from a structural standpoint.

Annular Rings.—The increase in diameter of trees is secured by the addition of a layer of new wood each year. The layers or rings are quite distinct, and barring accidents to the tree, the age may be calculated by the number of rings, which are composed of two parts, the spring wood and the summer wood, the former of which is thicker and more porous than the outer or summer wood part of the ring. The proportion of dense summer wood determines the weight, and to some extent the strength of the timber. The rings form the grain of the cut lumber. Cut radially, the rings are even and distinct,

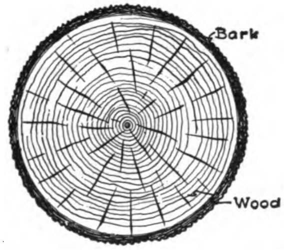


FIG. 292.—End section of log showing annular rings and medullary rays.

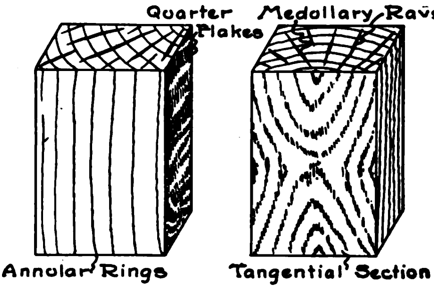


FIG. 293.

and flat cuts show the grain in broad, irregular, and V-shaped stripes.

Grain.—The grain of the wood is the factor which determines the beauty of the wood to a great extent. Fine-grained woods have a dense growth, and the rings are close together. Coarse-grained woods are of a porous growth. Wood is straight-grained if the layers of fiber are parallel to the trunk of the tree. Twisted or deformed growth affords the " curly " or " bird's eye " grain. The term " with the grain " refers to the direction along the trunk, and " across the grain " means perpendicular to the axis of the trunk.

Softwoods, or Conifers

The softwoods are widely distributed over the country, and constitute about 75 per cent of the lumber supply.

White Pine.—The white pine of the Central and Northeastern States, and the sugar pine of the Pacific Coast, is a light, easily worked, moisture-resisting wood. The trees are tall and straight with few branches. This wood is used largely for siding, millwork, shingles, and outside finish.

Yellow Pine.—The woods belonging to the class of hard yellow or Southern pine, are the most widely used of all woods for building construction. The varieties include the several species of long-leaf, Norway, short-leaf and loblolly pine. With the exception of Norway pine, which is found in the North, the pines are classed as Southern pine, and are distributed over the Southern States, from Virginia to Texas. Long-leaf pine is the hardest and strongest of the pines.

Yellow pine is used for all structural framing purposes, as it is stiff, strong, easily worked, even textured, and plentiful.

Fir.—Douglas fir, or Oregon pine, is used for framing, especially in long lengths. It is similar to yellow pine, and takes the place of pine in all framing in the Northwest.

Spruce.—There are several varieties of spruce, found in the Northern States and in Canada. The wood is light, soft and strong. It is used for paper pulp and for framing. It is not durable when exposed to the weather.

Hemlock.—This wood is soft, light, cross-grained, and brittle. It is used in the cheaper grades of construction, for framing and for rough boards.

Cypress.—This is a light, straight-grained, fibrous wood, found in the South, in swampy regions. It is very durable when exposed to the weather. It is especially desirable for silos, tanks, and siding.

Cedar.—The cedar tree produces a soft, stiff wood, but is not strong enough for building frames. It is very durable when exposed to the weather, and is used for shingles, siding,

and posts. Red cedar is prized as a cabinet wood for chests, clothes closets, pencils, and cigar boxes.

Hardwoods

Only a few of the many varieties of hardwoods will be considered here. There are many woods, such as cottonwood, that are used for building construction in some localities, but are not of general interest to commerce.

Oak.—There are many varieties of oak found in the United States. Oak is heavy, hard, and tough. White oak has these qualities to a marked degree. Red oak is more brittle and not so durable. The present scarcity of oak precludes its use for framing, and it is used for inside finish, floors, implements and vehicles. Oak not suitable for construction is used for posts and ties. Quarter-sawed oak is used for veneering doors, and cabinet work.

Black Walnut.—This is a heavy, dark brown, porous wood. It seasons well, takes a high polish, and is desirable for finish, veneering, and gun stocks.

Ash.—This wood is tough, quite hard, and has a straight grain. It has a limited use for house trim, and is used for handles, vehicles, and sporting goods.

Maple.—Hard or sugar maple is a heavy, strong, close-grained, white wood. It is suitable for flooring, tool handles, carving material and furniture.

Birch.—Birch wood is fine-textured, hard, and strong. It is used for furniture, for house trim, and veneered doors. Birch is used to imitate cherry and mahogany.

Poplar.—There are two kinds of poplar wood, the white and yellow. The wood is light, soft, and moisture resisting. It is used for outside finish, carriage bodies, for carving and turning.

Other Woods.—Basswood, elm, gum, cherry, and other hardwoods have a limited use in building work.

Qualities of Wood.—The qualities used to describe wood are hardness, toughness, and flexibility.

The hardness is influenced by the time of growth, seasoning,

and weight. Very hard woods include hickory, hard maple, black locust, and white oak. Hard woods include red oak, elm, ash, walnut and long-leaf pine. Soft woods include most of the conifers, and basswood, poplar, soft maple, etc. The quality of hardness should not be confused with the general classification of hardwoods and softwoods, which refer to the broad-leaf and conifers as a group.

Toughness is the ability to absorb shocks, together with strength and pliability. Elms and hickories are considered as tough woods.

Flexibility is the quality which enables a wood to stand distortion without breaking, and the tendency to return to the original shape.

Defects of Wood.—The growth of wood is a process of nature, and the quality of the wood varies with the climate, soil conditions, storms, and accidents. Some of the common defects are listed here.

Heart shakes are cracks radiating from the center of the tree, and are caused by the shrinking of the inner portion of the tree.

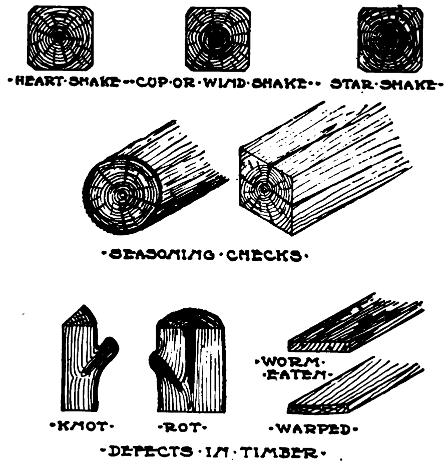


FIG. 294.

Star shakes radiate from the center of the tree, but are wider at the outer end, and are the result of a drying out of the sapwood.

Cup shakes are cracks between the annular rings caused by a twisting of the tree in storms.

Dry rot is the result of a fungus growth causing a dark tinge to the wood, and a softening and crumbling.

Knots are caused by the growth of live tissues around the stub of a broken branch, or over a wound. The importance of the defect depends upon whether the knot is loose or tight.

Sawing.—Sawing converts the timbers or logs into lumber. The band saw is preferable to the circular saw for cutting the logs. The two methods of sawing are plain sawing and quarter sawing.

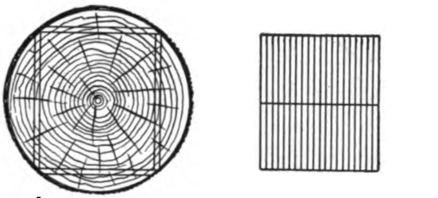


Fig. 295.

In plain sawing the log is squared by sawing off slabs. The squared log is then sawed into planks or boards, the cuts being made perpendicular to the radius, exposing the flat of the grain. Plain sawing is also known as tangential or bastard sawing, and is accomplished with less waste, and more easily than quarter sawing.

Quarter sawing is done to secure beauty, durability and strength. The radial cut exposes even layers of spring and summer wood, which has greater wearing qualities. On woods similar to oak, the radial cut exposes a very desirable grain.

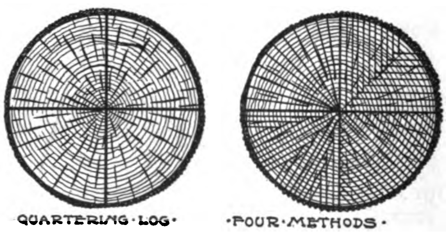


Fig. 296.

The log is quartered before being cut into boards or planks. There are several methods of cutting out the pieces, but the best results are secured when the cut is as near radial as possible. Quarter-sawed lumber is higher in price, and usually represents a more desirable material than plain sawed lumber.

There is always considerable waste in sawing. Slabs are used for lath and shingles, or firewood. Sawdust is used for insulation. All waste boards and sap boards are cut into small stuff, or lath.

Seasoning.—Live trees are cut for timber, and the logs contain a large amount of moisture. New surfaces are exposed in cutting, and it is necessary that all pieces be cured, or seasoned, before being dressed and used.

The two methods of drying are known as air drying and kiln drying.

In air drying, the lumber is racked carefully in yards or sheds, and allowed to cure in the air for six months or longer, until the wood is thoroughly dry.

In kiln drying the lumber is racked and placed in a heated room to cause rapid drying. The temperature is maintained at 170° F. for from four to ten days.

Lumber Measure.—The unit of lumber measure is the board foot. One board foot is 144 square inches, 1 inch thick, or the equivalent. A 1 by 12-inch board has a board foot for every foot of length. A 2 by 6 piece also has one board foot for each foot of length. A table of board measure, and board foot rule will be found on page 358. Lumber is usually sold by the thousand board feet.

Lumber Grades.—The grading of lumber varies with the section of the country, and the practices of the manufacturers' associations. Rough lumber or framing and boards are graded as No. 1, No. 2, and No. 3. No. 1 lumber is clear, straight, and free from knots. No. 2 admits some sound knots, and minor defects which do not injure the structural value of the stock. No. 3 lumber has some discoloration, large knots and may be warped or twisted. The best grade should be used for framing and exposed surfaces. No. 2 material is used for sheathing, roof boards, and covered areas. Second-grade framing may be used in small and cheap buildings. No. 3 material may be used for cheap or temporary construction where no great stresses are encountered.

Millwork and siding are graded as clear, select, and common.

The clear stock has no knots or defects, while the select and common are comparable to No. 2 and No. 3 stock.

Sizes.—Lumber is known as boards, plank, or timber, according to the size to which it is cut. Boards are sawed $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, 1 inch, $1\frac{1}{4}$ inches, and $1\frac{1}{2}$ inches in thickness, and from 2 inches to 12 inches wide, or wider in special work. Plank are commonly cut 2 inches thick, and from 2 to 12 inches wide. Timbers are 4 by 4 to 12 by 12 in common sizes, and larger for heavy structural or bridge timbers. In each case the size increases by 2-inch increments.

The length of lumber is usually specified in even lengths, from 10 to 20 feet. Longer or shorter lengths are special. The sizes given are the nominal sizes. Lumber shrinks somewhat during the handling process, and much of the commercial stock is sized or finished in the planer. The actual size of dressed lumber is from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch less than the nominal size. No piece lacking more than $\frac{1}{2}$ inch of the nominal size is permitted to be sold as the nominal size.

Millwork lumber such as moldings and quarter round are made in several styles and sizes. They are selected according to the kind of lumber desired, and the style. Purchase is usually made by the lineal foot, or by the piece.

Doors.—The standard thickness of doors is $1\frac{1}{8}$, $1\frac{3}{8}$, $1\frac{3}{4}$, and $2\frac{1}{4}$ inches. The heavier doors are used for outside or large openings, and inside house doors are $1\frac{3}{8}$ inches in average construction. Widths are from 2 to 3 feet, increasing by 2 inches. The height is from 6 to 7 feet, varying by 2-inch increments. The common residence doors are 2 feet 6 or 8 inches, or 3 feet wide, and 6 feet 6 or 8 inches, or 7 feet high. Doors are paneled into 1, 2, or 5 panels, or may be in the form of a slab. Veneered doors are better than solid doors when hardwood is used.

Windows.—Window glass is of single or double strength. The heavier glass should be used on all openings over 16 inches square. Windows may be single sash, casement or double hung. The double-hung, or two-sash window may be plain rail or check rail. Glass sizes increase by even inches in

width and length. The size of the sash varies, and the size of the window is designated by the glass size. In specifying sizes for either windows or doors, the width is always given first. The size of the sash is usually $4\frac{1}{8}$ inches wider than the total width of the glass, and 5 inches longer than the length of the glass. Windows are $1\frac{3}{8}$ inches thick in common sizes, and $1\frac{3}{4}$ inches in special.

The single-sash window is ordered by giving the number of panes, and the size of each. The double-hung window is ordered by giving the size of each light, or sash, glass size, strength, and how sash are divided. For example: one window, two light, 20 by 24 inches, double strength, top divided, four vertical divisions.

Roofing Materials

Whether the roof covering is of wood or other material, it is usually included in the lumber bill, and purchased from the lumber yard. A brief discussion of wood shingles and other roof coverings will be given here.

Wood Shingles.—Wood shingles are still the leading roof covering. They are of known quality, and the familiar methods of handling to secure a good roof have enabled them to maintain the lead. Of recent years attention has been given to the use of preservatives and stains, which add to the life of the shingle, and to the beauty of the roof. The best shingles are made of white pine, cedar, cypress and redwood.

Shingles average 4 inches wide, and 16 or 18 inches long. They are packed in bundles equal to 250 4-inch shingles, or four bunches to the thousand, and are sold by the thousand. One thousand shingles will cover slightly more than a square of roof, if laid 4 inches to the weather. The thickness of shingles is measured at the butts, and designated as the number of shingle butts in a width of 2 inches. Specified 5 to 2 means that the thickness of 5 shingle butts is 2 inches. The best grade of shingles is "5 to 2 extra clears." The next grade is "Star A Star 6 to 2."

The width of shingle exposed on the roof is expressed as a certain number of inches "to the weather." House roofs are usually laid 4 or $4\frac{1}{2}$ inches to the weather, and not more than 5 inches should be exposed in any case. The number of square feet of surface covered by 1000 shingles is determined by taking the average width of 4 inches times the exposure of 4 or $4\frac{1}{2}$ inches, multiplied by 1000 and divided by 144. The area covered per thousand, with different exposures, is given in Chapter XXXVII. An area of 100 square feet, or 10 by 10 feet, is called a square.

Following is a brief suggestion list, adapted from a bulletin of the National Lumber Manufacturers' Association, for the proper construction of a shingle roof:

Roof pitch not less than $\frac{1}{4}$.
Rafters, according to load, but not over 2 foot spacing.
Roof boards surfaced 1 side, 8 inches wide, spaced 2 inches apart. Nailed with 8 penny nails.
Best grade of shingles, none over 5 inches wide.
No joints directly over each other for 3 courses. Break joints $1\frac{1}{4}$ inches. Cover all nails.
Nails $3\frac{1}{2}$ or 4 penny, cut iron.
Pitch of $\frac{1}{3}$, expose $4\frac{1}{2}$ inches. Less than $\frac{1}{3}$, 4 inches.

Asphalt Roll Roofing.—Ready roofing, or roll roofing, is widely used as a covering for farm buildings. The material is purchased in rolls sufficient to cover 100 square feet, and the necessary nails and cement are furnished. The material consists of several layers of felt or burlap, impregnated with asphalt. The better grades are 3 and 4 ply, with asphalt coating. The surface may be plain, or coated with crushed slate particles, in red or green colors. There is a wide variation in the quality of roofings, and only the best grades should be purchased. The guaranteed roofings, warranted to last for ten, fifteen, or twenty years, are very serviceable. Seven-eighth inch galvanized nails are used with the roofing.

Asphalt Shingles.—Asphalt shingles are similar in composition to the roll roofing, but the appearance makes them more

desirable for residence or garage coverings. They are made in individual shingles, or in strips of 4 or 5 shingles together. The usual colors are red and green. The shingles are about 8 inches wide, and 12 inches long, and are laid 4 inches to the weather. They are sold in bunches of 100, and four bunches will cover one square. The sheathing boards must be laid tight for roll roofing or asphalt shingles.

Slate.—The use of slate is confined largely to the buildings in the eastern part of the country. The slate makes a rather heavy roof, and the first cost is high. This material can be secured in several colors, or mixed colors, and are in graded or random widths, and from 14 to 24 inches long. For common work the slate should be about $\frac{3}{16}$ inch thick. The slates may be punched or countersunk for the nails. A slate roof is permanent, of good appearance, and is preferred by many. Three pounds of galvanized nails are needed per square. The slates are sold by the square.

Galvanized-metal Roofing.—Metal roofing should be made of a high grade of iron or steel, galvanized. The thickness is indicated by the gauge number, the highest gauge number representing the thinnest metal. The sheets may be plain, corrugated, or shaped to represent tiles. Metal roofing is desirable where weather conditions, such as extreme heat and dampness, favor decay of wood shingles or the disintegration of roll roofing. There is a wide variation in the quality of roofing, and the appearance and conductivity of the metal do not favor the metal roof.

Roofing Tile.—The tile roof is heavy and massive, and is not used to any extent for farm buildings. The roof frame must be made heavy to carry the weight of the tile.

Asbestos Shingles.—A mixture of cement and asbestos is used to make the asbestos shingle. It affords a permanent, fire-resisting roof. The shingles are about $\frac{1}{8}$ inch thick and may be secured in a variety of sizes. They are usually furnished in a gray or red color. They may be laid similarly to wood shingles, or to form diagonal lines across the roof.

CHAPTER XXVIII

CEMENT AND CONCRETE

CONCRETE occupies an important place as a material of construction on the farm. Foundations, floors, and walks are built almost entirely of concrete, and its use is increasing for silos, barn walls, septic tanks, storage tanks, and in house construction.

Concrete work may be done on the farm at odd times

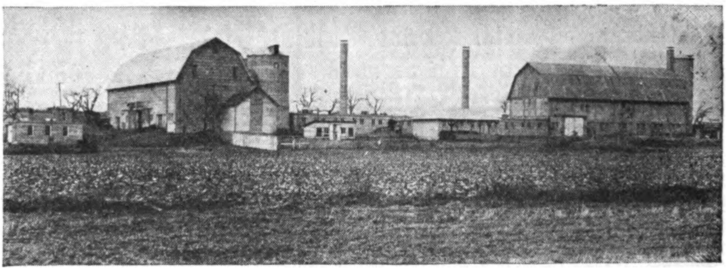


FIG. 297.—A dairy farm, buildings constructed largely of concrete.

by the usual farm labor, and is a very economical material if sand and gravel are near at hand. It is important that the reader interested in farm buildings should understand the principles of concrete construction.

Concrete is a permanent, fire-resisting, and adaptable material, easily made and reasonably low in cost, which makes it advantageous for farm work.

Definitions.—Portland cement is defined by the Society for Testing Materials as "The product obtained by finely pulverizing clinker by calcining to incipient fusion an intimate

mixture of properly proportioned argillaceous and calcareous substances, with only such additions subsequent to calcining as may be necessary to control certain properties. Such additions shall not exceed 3 per cent by weight of the calcined product." The above definition means that Portland cement is composed of approximately 25 per cent of clay or shale, and 75 per cent limestone, burned, and finely ground, with not over 3 per cent of gypsum added to control the time of setting.

Concrete is the product resulting from the mixture of cement with inert materials, such as sand and gravel, and sufficient water added to wet the entire mass.

" Aggregates " is the term used to denote the inert materials such as sand, gravel, broken stone, or cinders.

" Portland " is a term used to denote manufactured cement, and contains approximately the proportions specified by the Society for Testing Materials.

Natural Cement is the product of rock which contains the necessary ingredients for cement in about the correct proportions.

Amount Used Annually.—The yearly production of Portland cement is more than 100 million barrels. The production of natural cement has decreased until it is no longer a factor in the building trades.

Method of Marketing.—Cement is sold in paper bags or cloth sacks each containing 94 pounds. Much cement is sold in barrels, containing four bags. Large contracting firms using cement in quantity purchase it in bulk, in carloads.

Any well-known brand of Portland cement is suitable for farm work, and the availability will usually determine the brand. Cement should be reasonably fresh, free from hard lumps, and should not be allowed to become wet before using.

Aggregates

Sand.—Sand used in concrete work should be clean, and free from vegetable matter, and when containing an excess of dirt must be washed before being used. Sand is the pro-

portion of the aggregate which is less than $\frac{1}{4}$ inch in diameter, and should be well graded from very fine to $\frac{1}{4}$ inch, as a large amount of very fine material decreases the efficiency of the concrete. Sharpness does not affect the strength of the concrete to a noticeable extent.

Gravel.—The most easily secured and widely used coarse aggregate is gravel. Gravel ranges in size from $\frac{1}{4}$ inch up to a size determined by the character of the work. For small work the size of the particles should not exceed 1 inch in diameter, while for large work the gravel may contain pieces $2\frac{1}{2}$ or 3 inches in diameter. As usually found, gravel and sand are mixed together in the beds or pits, and the mixture is known as "bank run" material. The bank-run gravel usually contains an excess of sand, and for best results should be screened and remixed in the correct proportions.

Crushed Rock.—This material may be used in the concrete mixture in place of gravel. Well-graded, clean crushed rock is preferred to gravel for some work. The rock should be free from rock dust and well graded in size.

Cinders.—Cinders are used as the coarse aggregate where a light-weight concrete is desired. Cinder concrete is not so strong as ordinary concrete work. The cinders should be free from dirt and dust.

Water.—The water used for concrete work should be clean, and free from dirt and vegetable matter, which injures the concrete work.

Proportioning.—The object of mixing the aggregates with the cement in certain proportions is to secure a dense, strong concrete, with the greatest possible amount of coarse material, to reduce the cost. Concrete designed to withstand heavy stresses or concrete in thin walls must be rich; that is, it must have a large proportion of cement to coarse aggregates. For large masses, such as fills and footings, the concrete may be lean, or contain a large percentage of inert materials. For various uses, certain standard proportions have been worked out, which give good results. To understand the standard proportions, it is necessary to refer to the following dis-

cussion, upon which the so-called standard proportions are based.

If a fairly well-graded volume of sand is analyzed, it will be found that very nearly one-half of the volume consists of air spaces around the sand particles, which are known as voids.

If a finely pulverized material such as cement is added to a given volume of sand, it will be found that the voids in the sand will hold 1 part of the fine material in each 2 parts of the sand, and the resulting volume will be very little greater than the original volume of sand.

Likewise, if the mixture of cement and sand is combined with gravel, it will be found that the voids in the coarse material

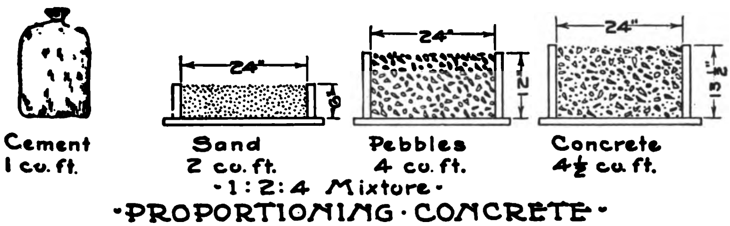


FIG. 298.

will hold 1 part of the mixture to 2 parts of gravel, without greatly increasing the volume of the gravel.

In terms of cubic feet, it follows that 1 cubic foot of cement, combined with 2 cubic feet of sand, and 4 cubic feet of gravel, will produce slightly more than 4 cubic feet of dense material. The amount of cement is sufficient to fill the voids in the sand, and coat each sand particle with cement. The sand-cement mixture will coat each particle of gravel, and together they form a mixture which is strong, dense, and cheap when properly mixed, placed, and cured. Aggregates vary in proportion of voids, and likewise in density and strength. The usual proportions, however, are based on the assumption that the above theory holds good under average conditions.

Standard Proportions.—The proportion of cement, sand, and gravel is expressed as follows: 1:2:4, meaning 1 part

cement to 2 parts sand and 4 parts gravel. The following proportions are most often used.

1:2 or 1:3 mixture of cement and sand, without gravel, is used for top coatings on walls, tanks, or walks. It is used for cement mortar, and in cases where a fine, rich concrete is desired.

1:2:3 is a rich mixture for tanks, fence posts, troughs, and similar work where strength is necessary.

1:2:4 is the standard mixture for farm construction, for foundations, floors, columns, silos, and other farm construction.

1:2½:5 is used in large masses, such as retaining walls, where strength is not so necessary as cheapness.

The above proportions are for screened sand and gravel in the correct amounts. For bank run concrete, the mixture of 1:4 corresponds to the 1:2:4 mixture, and 1:5 mixture of bank run gravel is very little stronger than a graded mix of 1:2½:5. The error should not be made of assuming that a 1:2:4 mixture is equivalent to a 1:6, for in the first case there is one bag of cement to about every 4½ cubic feet of finished concrete, while in the latter case the cement in the finished work is but one-sixth of the total material. It is recommended that, so far as possible, all of the materials be screened and remixed in the graded proportions.

Amount of Water.—The amount of water to be added to the dry material is usually left to the judgment of the builder, and is based on the following grades of wetness:

Dry Mixture.—Enough water is added to give a consistency similar to moist earth. When a quantity of the mixture is pressed in the hand it will form a ball which will hold together. A dry mixture is used for molded articles from which the forms are immediately removed, such as cement blocks and tile. The dry mix give a porous concrete as compared to the other mixtures.

Medium Wet Mixture.—A mixture of medium wetness is ordinarily referred to as being of a "quaky" or jelly-like consistency. After being placed a medium-wet mixture should show a slight amount of water on the surface of the

concrete. This mixture is not tamped, but is rammed and spaded to eliminate air pockets and to give a smooth surface next to the forms. This consistency is the most widely used for farm work, for sidewalks, tanks, walls, and the like.

Wet Mixture.—The wet mixture has enough water added to allow the concrete to flow into place. It is necessary to have tight forms for wet mixtures. The wet concrete affords a tight, impervious wall, and is used in large structures and reinforced work.

Mixing.—The two methods of mixing concrete are hand and machine mixing. Hand mixing requires a considerable amount of labor, and a small concrete mixer should be secured where any large amount of concrete work is to be done.

The tools necessary for hand mixing are a mixing platform measuring box, water barrel, and square-end hand shovels. The mixing platform should be 10 by 12 feet in size, smooth on top, and as nearly water-tight as possible. Two-inch lumber is best for the construction. A measuring box should be used to determine the correct amount of each ingredient. A box 18 by 24 inches, and 8 inches deep will hold 2 cubic feet; it is made without a bottom, and is set on the mixing platform for filling.

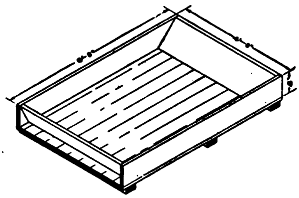


FIG. 299.—A mixing box for concrete.

The method of hand mixing usually followed is to spread the crushed stone or gravel on the platform, and spread the sand and cement evenly over the coarse material. The whole mass is turned completely over by shoveling until the batch is a uniform gray color, and the cement particles cover the aggregates. The correct amount of water is then added, and the mixture thoroughly stirred until the whole batch is of the desired consistency. It is sometimes considered best to mix the sand and cement first, and add the gravel afterwards.

Small mixers equipped for hand or engine power are economical for farm work. The cost of a good small mixer

will be less than $100, and it will save the labor of at least two men on the job. The usual sizes are the half and full sack size.

Placing.—All concrete should be placed within thirty minutes after being mixed. The dry mix must be tamped into the forms, and the forms or molds may be removed immediately. The quaky mix is spaded and rammed into place, and the wet mixture is poured. In warm weather it is possible to remove the forms from small work at the end of twenty-four hours. Forms should not be removed from walls or foundations for several days. In cold weather concrete requires much longer to cure. All work should be kept moist for a week or more, and shaded from direct sunlight.

Forms.—It is important that the forms be sufficiently strong and well braced to hold the concrete until it sets. Concrete in a wet state weighs about 150 pounds per cubic foot, and requires heavy bracing and forms to hold it in place. For foundations and barn walls forms may be built of rough lumber, if the appearance is not important. For exposed work, the forms should be made of smooth lumber. The cost of lumber for forms is a considerable item. To reduce the cost the forms are often made of material that may be used later in the building. Manufactured forms of metal are desirable, as they are smooth, easily handled and may be used many times. Metal forms are especially desirable for circular construction such as silos.

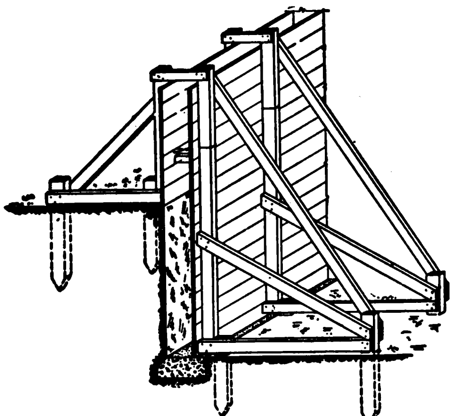


Fig. 300.—Forms for concrete foundation wall.

Reinforcement.—Reinforced members in farm buildings should not be attempted without the aid of a competent engineer. The amount of steel, the proportion of steel to concrete, the location of the reinforcement, and the load to be applied, all affect the design of the reinforced members. No attempt will be made in this text to cover the subject of reinforcing. For small work, such as fence posts, well curbing, and small stock tanks, the amount and kind of reinforcement are so well known that the work can easily be done if directions are followed.

The economy of reinforced concrete lies in the fact that concrete is comparatively low in cost, and is strong in compression, thus reducing the cost as compared to the use of steel alone. The concrete is weak in tension, hence it is necessary to add an amount of steel sufficient to take all of the tension. Concrete and steel contract and expand equally with heat and cold and thus avoid internal strains.

The reinforcing steel should be placed in the member in such position that it will receive the tensile stress. In the case of a beam, the reinforcement should be placed near the bottom. The fence post is reinforced at the corners, since the stress may be applied from any direction. A simple experiment performed by the Iowa Experiment Station shows the importance of the correct location of the steel. Four test beams, each $1\frac{1}{2}$ by 3 inches by 3 feet long were made from the same batch of concrete. One beam had no reinforcement, and the other three had reinforcement in the top, center, and bottom, respectively. The beam with no

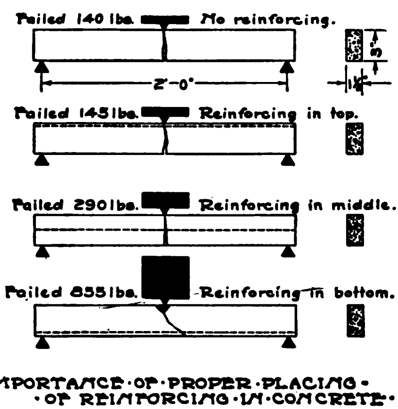


FIG. 301.—Results of an experiment to demonstrate proper placing of reinforcement.

steel broke when a total of 140 pounds was applied at the center. With the steel at the top, the second beam broke at 145 pounds. The reinforcement at the center sustained a weight of 290 pounds, while the beam properly reinforced with the steel near the bottom required a load of 855 pounds to break it.

The following formula for tank reinforcing is taken from Taylor and Thompson's "Treatise on Concrete":

$$A_h = \frac{62.4\,HD}{2\,f_s}$$

where H = Height of tank above section considered;
D = Diameter of tank in feet;
A_h = Area of steel required (square inches, per foot of height at section considered);
f_s = 16,000;
62.4 = Weight of water per cubic foot.

Finishing.—Much of the sidewalk and floor work is made in two courses, the top coat or finish course being richer, and made of fine materials. The top course is usually made of a mortar of cement and sand in the proportion of 1:2. The rich top course improves the appearance and increases the wearing qualities of the concrete.

A smooth finish is secured by means of a steel trowel, and the rough finish is made by "brooming" with a heavy broom, or "floating" with a wooden trowel. The use of edging and jointing tools is essential on the careful job. Tanks and cisterns may be given a finish coat of cement and sand in the form of a plaster, troweled smooth. The inside of concrete silos is often given a wash, made by mixing pure cement and water in the form of a paste.

In finishing large areas of concrete, as floors, sidewalks, or pavements, it is necessary to provide expansion joints. For inside work the joints may be 15 feet or more each way. Sidewalks should have a joint every 25 to 30 feet. Feeding floors and similar construction should have a joint about every 10 feet each way. The best joints are made by leaving an

interval of 1 inch through the concrete, and filling the space with asphalt. A sand joint in the bottom course, and a cut joint directly above in the finish course will serve the same purpose.

Cold-weather Concreting.—In the past, concrete work in the North usually ended with the coming of winter, but at the present time many buildings of concrete are built in freezing weather. The advantage of winter concrete work on the farm is that plenty of time is available for doing the work without outside labor. The troubles encountered, and the precautions which must be observed, are: (1) Cold delays hardening or setting, and it is necessary to leave the forms on longer than in warm weather; (2) the finished work must be protected from abrupt changes in temperature, and from alternate freezing and thawing; (3) materials used in the construction must be heated, to aid setting, and to prevent the possibility of ice becoming embedded in the concrete.

For winter concrete work, the aggregates and the water should be heated, the forms warmed, if metal is used, and all work should be protected immediately after placing, by means of straw, manure, or a cloth covering.

Concrete Construction

Mortar.—Portland-cement mortar is recommended for use with hollow tile construction, for walls, silos, and foundations. The mortar is made by mixing 1 part of cement with $2\frac{1}{2}$ or 3 parts of sand, and 10 per cent, by volume of lime putty. The lime gives a mortar of better working qualities, and greater strength, than the pure cement and sand mixture.

Floors.—Concrete floors for farm buildings may be laid as single- or double-course floors. The single-course floor is made from one thickness of concrete, while the double floor has a bottom course of medium or lean concrete, covered with a top course, $\frac{3}{4}$ to 1 inch thick, of rich cement mortar.

Floors may be laid directly on the ground if the soil is porous and well drained. For moist, wet soils, there should

be a fill of about 6 inches of cinders or gravel, well packed, to keep the floor dry.

A mixture of 1 : 2 : 4 is the best for all floors, or with bank run gravel, the mixture should be made 1 : 4 or 1 : 5, of quaky consistency. To drain the surface all floors should be given a slight slope or pitch, which will vary from $\frac{1}{20}$ to $\frac{1}{4}$ inch. The two-course floor is considered the best. Floors are finished smooth with a steel trowel, or rough floated with a wood trowel.

Dairy-barn Floors.—In laying the dairy-barn floor, there are a few special directions that should be followed. The curb which holds the stall anchors should be made first, and of a very rich mixture, for strength. The spacing should be according to the plan, and must be accurate. As the concrete sets, the top of the curb is smoothed and the corners finished. The feed and litter alleys are made next, and given a slight pitch for drainage. The standing platform is made to receive the stall partitions. If cork brick or wood blocks are used, the space must be made to fit them. The manger and gutter are made last.

Feeding Floors, Pavements, and Walks.—Barnyard pavements and floors may be made in one course, of a 1 : 2 : 4 mixture. The ground should be well drained, to avoid moisture under the concrete. Expansion joints should be provided at intervals of about 10 feet in either direction. Sidewalks are made in two courses, marked into squares while green, and finished with edging tools and jointers. The sidewalk is usually finished with a wood float or trowel.

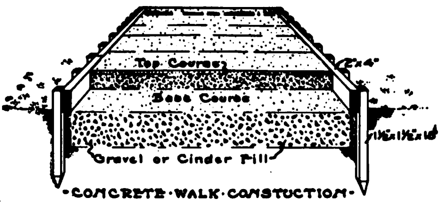


Fig. 302.—Concrete walk construction.

Foundations.—It is often possible to use the earth trench as a form for the foundation. If the ground is very dry and porous, it is desirable to line the trench with building paper, to prevent the absorption of water from the concrete. A medium or lean mixture is

satisfactory for foundations, and reinforcing is not necessary if the foundation is carried below the frost line to firm soil. Care must be taken to secure a foundation that is level and square. Where built-up forms are necessary, they should be braced, and tied together to prevent spreading.

Walls.—Except for silos, monolithic walls are not widely used in farm buildings above the foundation. It is necessary to make barn walls 10 inches thick and the smaller buildings have walls 6 to 10 inches thick. A mixture of 1 : 2 : 4 or 1 : 2 : 3 should be used. Reinforcing is necessary around openings. Double-wall construction is preferable to the single wall for stock buildings. The problem of openings in the concrete wall is rather difficult of solution, and considerable experience in concrete work is required for effective results.

Fence Posts.—Concrete posts should be made of a 1 : 2 : 3 concrete, or of a 1 : 3 cement and sand mixture. The reinforcing used is four $\frac{1}{4}$-inch steel bars for each post, one in each corner. Corner posts should be built in place, and are more heavily reinforced. Line posts are 3 by 3 inches at the top, and 5 by 5 inches at the bottom, and 7 feet long. Several shapes are in use, but the ordinary rectangular type is considered the most satisfactory. Posts should not be removed from the form for at least twenty-four hours, and cannot be used for thirty days or more. In the best construction the fence is fastened to the post by a loop of wire around the post.

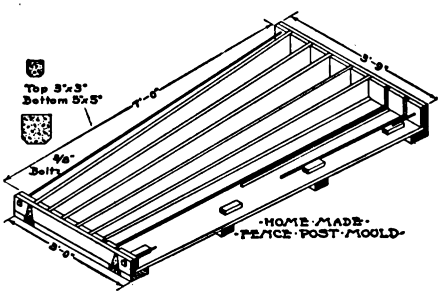


Fig. 303.—Concrete fence post molds, home made.

Cement Blocks.—Because of the difficulty of constructing monolithic concrete walls on the farm, the cement block is a popular building material, especially for small buildings. The blocks may be made in a small factory, or on the farm at any

season of the year and laid up in a manner similar to hollow tile. Blocks should be made of a 1 : 3 mixture of cement and sand, and of a dry consistency. The principal objection to the block is that it is somewhat porous, and is likely to allow the passage of moisture through the wall.

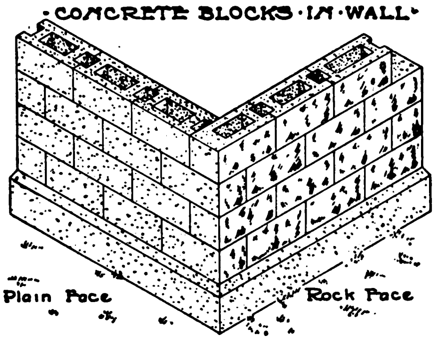


FIG. 304.—Concrete block wall construction.

Cement Staves.—The staves are a patented cement product used principally for silo construction, but have found some use in replacing the heavier blocks in small buildings. The cement stave is discussed in Chapter XVI.

Cement Stucco.—The composition of Portland cement stucco is 1 part cement, $2\frac{1}{2}$ parts sand, and lime putty equal to about one-third the volume of the cement. Coloring matter may be added to secure desired shades. Stucco may be applied to wood, patent, or metal lath. When placed over masonry or sheathing, the lath must be furred out $\frac{7}{8}$ inch, in order to allow a proper bond. The wall to which stucco is applied must be well framed and braced to prevent cracks in the covering. The more common stucco finishes are smooth-troweled, pebble-dash, rough-cast, sand-floated, and exposed aggregates.

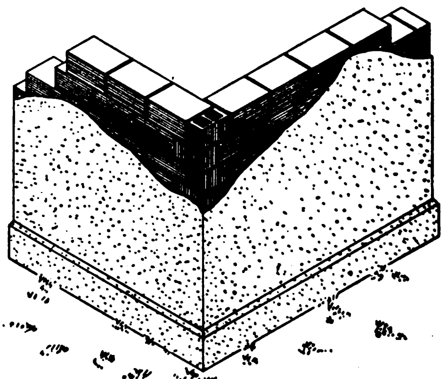


FIG. 305.—Cement stucco over clay block.

CHAPTER XXIX

BRICK AND HOLLOW BUILDING TILE

Brick is one of the oldest building materials of the permanent type. Hollow tile is similar to brick in composition. The tile are molded into shapes having air cells, which save material and weight and make possible the manufacture of larger units. Hollow tile form dead air spaces in the wall when laid. The brick and tile are made from clay, ground, mixed, molded, and burned. The burning consumes all organic matter and fuses the clay into a hard, solid mass.

Clays.—Clays may be found pure, or containing impurities which must be removed. The top soil is stripped off, and the clay mined and dug, after which the stones and impurities are removed, and the manufacture carried on by machinery.

Molding.—The three processes of molding are the soft-mud, stiff-mud, and dry-clay processes. In the first, about one-fourth volume of water is added. In the second the mud is made stiff, and in the dry process, the clay as it comes from the pits is molded under high pressure. The common method of molding is to force the material through a pug mill into a die, and to cut the pieces to length. Another method is to force the clay into molds.

Drying and Burning.—The blocks or brick are racked and allowed to dry in an open shed. They are then burned in kilns from six to fifteen days, depending upon the character of material, fuel, etc.

Colors.—The method of burning and the composition of the clays determine the color of the brick. Iron produces tints ranging from red to yellow. Iron oxide gives a bright red. Iron and lime combined give a cream color, varying

sometimes from red to brown. Iron with magnesia produces a yellow tint.

Classification of Brick.—According to the method of molding, brick are classified as soft, stiff-mud, pressed, repressed, and sanded brick. Pressed brick are made by the dry-clay process, while repressed brick are molded from soft mud, partially dried, and then pressed under heavy pressure. Sanded brick are molded from soft mud, with sand sprinkled in the forms or molds.

The classes according to the burning are arch, hard, and soft brick. The brick which form the sides of the arch in which the fire is built are overburned, hard, and brittle. The hard-burned brick, or those on the inside of the pile in the kiln, called cherry or body brick, are the best. The brick on the outside of the pile are underburned, soft, light, and absorbent. They are used for fillers and backing. They are often termed salmon brick.

Brick are classed as to form and use into face, special, and common brick. The face brick are used for exposed surfaces, and are either smooth, either pressed or enameled, or rough. Special brick are made for special purposes. Common brick are sometimes classed separate from face brick, and are those ordinarily used for chimneys, piers, etc.

Size and Weight.—The usual size of brick is 8 by 4 by $2\frac{1}{2}$ inches, although there is some variation. The adopted standard at present is $8\frac{1}{4}$ by 4 by $2\frac{1}{4}$ for common brick, and $8\frac{3}{8}$ by $4\frac{1}{8}$ by $2\frac{3}{8}$ inches for pressed brick. Bricks weigh from 6 to 7 pounds each and brick masonry weighs 125 to 150 pounds per cubic foot.

Quality.—Bricks are classed as No. 1, No. 2, and culls. Good brick should be hard, uniform in shape, color and hardness, free from warps, cracks, and irregularity in the edges.

Mortar.—Mortar is a pasty material used to bond the bricks into a solid mass. It is made from lime or cement, mixed with sand. One part of lime to 4 parts of sand, or 1 part cement to 2, 3, or 4 parts of sand is used. Cement mortar is " short " and hard to work, but is stronger than lime mortar,

and should be used in damp places, below grade, or where strength is required. Lime mortar is easy to work, and sticks well, but is not strong. An excellent lime-tempered mortar is made by adding lime to cement mortar, at the rate of 10 per cent by volume. For decorative purposes, coloring matter is often added to the mortar. The tint brings out the joints,

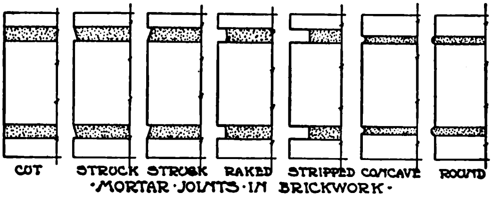


FIG. 306.

and is used much in presses and texture work. Too much coloring matter weakens the mortar.

Bricks in Wall.—Brick are laid up in courses. One brick width makes a 4-inch wall, two a 9-inch wall, with an increase of 4 inches for each additional brick. Brick are laid in a bed of mortar, and their ends "buttered" or covered to make a tight vertical joint. The thickness of the mortar joint varies from $\frac{1}{8}$ inch for pressed brick, to $\frac{3}{8}$ or $\frac{1}{2}$ for common brick, and $\frac{1}{2}$ to $\frac{3}{4}$ for texture brick. The joint is finished by being struck, weathered, raked, set back, rodded, or pointed. Pressed brick require a struck, pointed, or rodded joint; texture brick require the cut or raked joint; while the common brick are usually laid with the cut joint.

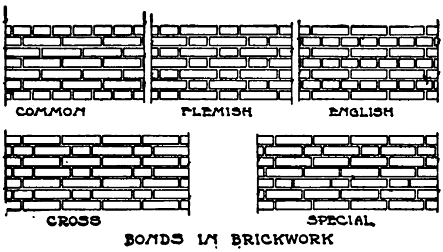


FIG. 307.—Common bonds in brick work.

Bonds.—Bricks are bonded for designs and for strength of wall. Headers are brick laid crosswise of the wall, and stretchers are laid along the wall. There are five bonds used in laying up walls.

1. Common bond consists of five courses of stretchers and one course of headers.
2. Flemish bond consists of alternate headers and stretchers in the course.
3. English bond has alternate rows of headers and stretchers.
4. Cross bond consists of one course of stretchers, and one course of Flemish bond.
5. Diagonal bond consists of a step effect in the vertical joints. It is used for decorative effect.

Wall ties are often used to tie the face brick to the back wall. Metal ties consist of heavy strips of corrugated galvanized metal about $\frac{3}{4}$ inch wide and not less than 8 inches long. Clipped or blind headers consist of bricks placed diagonally in the wall. The inner corners of the stretchers are clipped off so the corner of the bonding brick extends into the surface course. Clipped headers are placed in every sixth course.

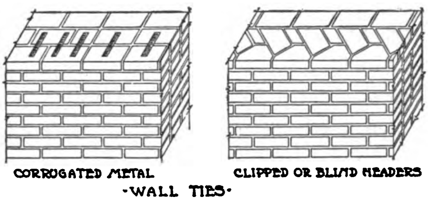


FIG. 308.—Common forms of wall ties.

Points in Construction.—Brick should be kept covered and dry in cold weather, and during warm weather they should be wet before laying in the wall. The top of the wall should be covered to keep off rains. The wall should be kept nearly level during the construction, that is, it should be built to about the same height around the building, as cracks are formed from settlement where new wall is joined to the old. After the wall is laid and has settled, it should be washed down with a weak solution of muriatic acid to remove the stains from the surface, the washing being begun at the top of the wall. It is then washed down with a hose.

Hollow Building Tile.—Tile are made in various sizes, depending upon the uses. The size ranges from 4 by 4 by 12

for building work, to 12 by 12 by 15 inches for structural work. Tile are classified as to use, into, floor and reinforcing, special, partition and wall, and curved and radial-cut tile.

Floor and Reinforcing Tile.—These tile are used to fill in between beams, joists, and girders, usually as fillers to reduce the weight of the construction. In long-span floor construction tile cores are used between T-beams to save weight.

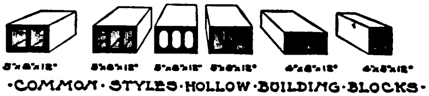


Fig. 309.—Common styles of hollow clay building blocks.

Special Tile.—Special tile are usually used in fireproofing, and are made in a variety of shapes to protect the structural steel from fire. They are not used in farm buildings.

Wall Tile.—These tile are usually 5 by 8 by 12 inches, laid in either a 5- or an 8-inch wall. Several styles may be secured in the wall tile for exposed, veneered, or stucco walls. The tile are graded as firsts and seconds, the latter being spawled, warped, cracked, or underburned. The firsts are hard, true, and without defects. When struck with a hammer they have a metallic ring. The seconds may be used for tile floors.

Tile Floors.—Hollow tile are laid in a sand cushion 1 inch thick, over a cinder or gravel fill of about 6 inches depth. They are laid close together and tamped. About $\frac{3}{4}$ inch of rich cement mortar is placed over them and allowed to fill all holes or depressions and to make a smooth surface. For poultry house and hog house, this floor is very satisfactory. For heavy stock, at least 2 inches of concrete should be used over the tile. The floor should be given sufficient slope for drainage. The value of this floor is that the dead air space prevents the conduction of cold and moisture through the floor.

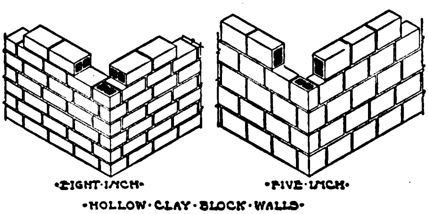


Fig. 310.—Hollow clay block walls.

Tile in Walls.—The joints in the tile wall vary from ½ to ¾ inch thick. The bed joints should be slushed, then the center lifted out with trowel and the cell walls "buttered" to make a tight vertical joint. After the tile are laid the joints should be pointed with the trowel to insure a tight joint. The mortar should be a lime-tempered cement mortar.

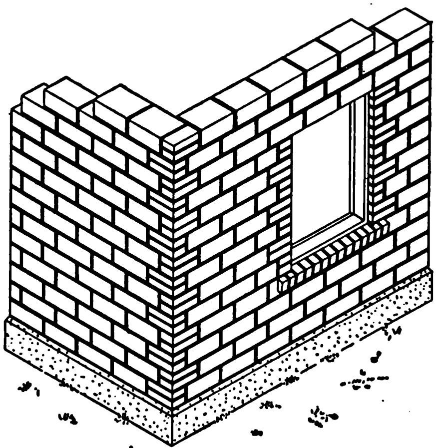


FIG. 311.—Use of brick with blocks.

The tile 3 and 4 inches thick can be laid quite easily, as the mason can hold the tile in one hand while applying the mortar. The principal difficulty in laying the tile wall is to secure a tight vertical joint, as the thin webs make it difficult to secure a good bond. The three-cell tile, 5 inches or more thick affords a better vertical bond than the two-cell tile. To secure a good building it is necessary to have experienced help to lay up the wall.

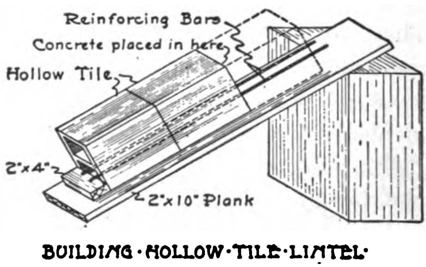


FIG. 312.—Method of making hollow block lintels.

Lintels for Tile Wall.—Lintels may be quickly made on the job by joining two or more tile, end to end, placing steel through the air cells for reinforcing, and filling the cells with a cement mortar. To make the lintels, a stiff plank is set at an angle of about 30°, and a block nailed to the lower end of the plank. The tile are rested against the block to prevent sliding,

with the tile laid end to end, to make the required length. The steel bar should be placed in the lower cell, and held away from the edge of the tile in order that the mortar may bond completely with the steel. It is best to tamp the mortar around the steel in the two lower tile first, and add a tile at a time, tamping the mortar into the cell until the desired length is secured. Lintels of this type may be used for all single doors and windows. For wide openings a reinforced lintel should be used.

Closure Tile.—Four-, 6- and 8- inch tile may be secured for closure tile. The 8-inch tile laid on end serves as the corner tile. Brick are sometimes used to fill in the corners. The tile should be laid with joints broken, and are usually laid in the wall as stretchers

Scored Tile.—The surface of the tile coming in contact with the bed joint is often scored, or roughened, to afford a better bond with the mortar. For plastering or stuccoing directly onto the tile, the surface is usually scored.

Silo Tile.—The use of tile for silos and round or curved buildings has led to the development of the curved and radially cut tile, which fit closely at the ends, and form a smooth wall. They are curved at the time they are made by forcing the soft form from the mold over rollers.

Silo blocks are made for 4-, 5-, and 6-inch walls. The 4-inch wall is widely used, because of the ease of laying. The 5-inch wall permits the use of three-cell tile.

Absorption of Silo Tile.—Since the silo must be air and water tight, and because of the danger from spawling and crumbling when water freezes in the pores of the tile, it is important that the tile have a low absorption test. Blocks should not absorb more than 7 per cent moisture when immersed for seventy-two hours. For a fair test, three blocks should be tested. They are first dried at 212° until they no longer lose weight. The blocks are then weighed at room temperature, immersed for seventy-two hours, then wiped dry and weighed. The increase weight shall be considered as the absorption, and the absorbed weight, divided by the dry weight gives the per cent of absorption.

In place of immersing for seventy-two hours, they may be placed in rain water and boiled for five hours, cooled, and dried. Otherwise the test is the same as described above. The absorption in this test should not exceed 9 per cent.

Glazed Tile.—Glazing improves the appearance of tile, and makes the surface more impervious to moisture. The salt-glazed tile is not necessarily stronger than the unglazed. All tile for silos or other buildings should be hard burned, of a uniform color, and free from lime spalls and cracks.

Other Uses for Curved Tile.—Tanks, grain bins, milk houses, and other small buildings are now made from silo tile, in round or curved shapes.

Use of Stone in Farm Buildings.—The use of stone in farm structural work is limited, and no discussion is given in this text. For practical purposes, concrete, brick, and tile are fully as economical, and are more easily handled. Where stone is abundant, it may be used for foundations and lower walls. The appearance of rough stone is favored by many for house and porch foundations. For walls, the stone should be laid in cement mortar and the wall made 16 to 30 inches thick.

CHAPTER XXX

MECHANICS OF FARM BUILDINGS

For economy of construction, it is necessary that the different members of the building be strong enough to withstand the strains put upon them, and yet not be excessively heavy. More material than is necessary is wasteful, both in the material itself and labor. Most of the framing members of the various farm buildings have been figured theoretically, and tested in common practice sufficiently to enable the progressive farmer or builder to secure strength and economy. This method of following common usage is called "standard practice."

In some cases, as in the timber frame barn, the common practice has been to use heavy timbers and more bracing than is called for by the needs of the building. Then there are certain problems, such as reinforced concrete work and silo construction, that should be figured by a competent engineer if best results are to be secured.

It is not possible here to discuss the subject of mechanics in detail. Rather, it is intended to consider the more common problems and essential definitions to enable the reader to understand the mechanics of the farm buildings.

Definitions.—The following definitions should be fully understood:

Stress.—The force within a body which tends to resist deformation.

Strain.—The deformation produced in a body by reason of internal or external stresses. The four kinds of stresses which produce strain are (1) tensile stress, which tends to pull the fibers or stretch a body; (2) compressive stress, tending to

crush the fibers; (3) shearing stresses, tending to slide one particle or fiber over another; and (4) transverse or bending stresses, tending to break or bend a structural member across the grain.

Ultimate Strength.—Equivalent to a load just sufficient to cause failure in the member.

Safe Load.—Load which may be applied without danger of breaking, or undue strains. It is only a fraction of the breaking load.

Factor of Safety.—Ratio of the safe load to the ultimate strength or breaking load. The factor of safety of steel is 4. The breaking load is about 60,000 pounds per square inch, and the safe load is taken as 15,000 to 16,000.

Moment of Inertia.—A property of a structural member involving the depth and width, and which determines its ability to resist stresses. It is designated by I and is equal to $\frac{1}{12} bd^3$, where b is the width and d the depth.

Section Modulus.—Equivalent to the Moment of Inertia divided by the distance from the neutral axis to the "outer fiber," or, in rectangular beams, since the neutral axis is at the center, the distance is $\frac{1}{2}d$, and the formula is $\frac{1}{12}bd^3$ over $\frac{1}{2}d$, or $\frac{1}{6}bd^2$.

Beam.—A horizontal body, resting on supports, and loaded to produce transverse stresses. A simple beam is supported at each end. A continuous beam has three or more supports. A cantilever beam has one end fixed, and the other overhanging the support. Distance between supports is called the span.

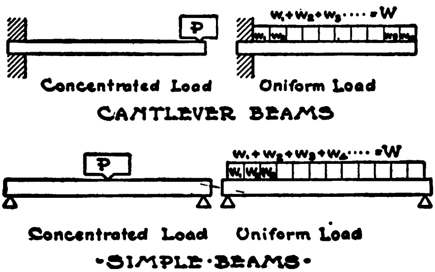


FIG. 313

Loadings.—Beams are uniformly loaded, when the load is evenly distributed along the entire beam, between supports. Concentrated loads are applied at one point, usually the center.

Live loads are those suddenly applied, as in the case of a car driven over a bridge. Dead loads are those applied gradually, and which remain at rest. Live loads require a design to bear twice as much load as if the load were applied gradually.

Moment.—Moment is the tendency of a body to rotate about a fixed point. It is equivalent to the product of the force times the distance from the fixed point. In a cantilever beam 4 feet long and bearing a load at the end of 100 pounds, the moment is 400 foot-pounds. In building construction the sum of the moments about any point must be equal. It follows that if the beam is able to support a given load, there must be internal resisting forces to neutralize the external moments.

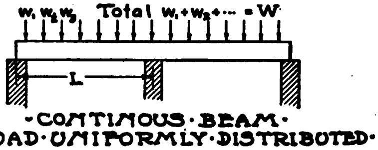


FIG. 314.

Reactions.—A reaction is the force that must act upward, as in the beam support, to carry the weight of the member and the load. If the load is uniformly distributed or at the center, the reactions at each support will be equal. If the load is not uniform, the moments are taken about one point, and knowing the distance between supports, there is but one unknown quantity, namely, the reaction at the opposite support, which can be solved algebraically. When the reaction opposite to the support used as the center of moments is found, the total load minus the one reaction will give the other.

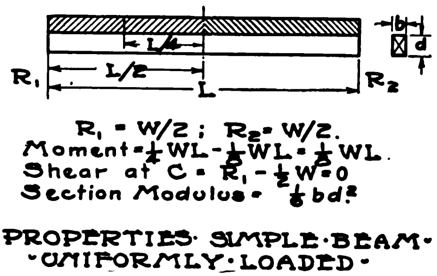


FIG. 315.

Shear.—The loads on a beam, and the upward reactions at the supports tend to slide the particles within the beam, vertically. At any point in a beam the shear is equal to

either reaction minus the loads between the reaction and the point considered. If a simple beam is considered, with a uniform load, the shear will be greatest at the support which is equal to the reaction, and the shear is zero at the center of the beam.

Bending Moment.—Bending moment is the tendency to produce bending at any point in a beam. It is equal to the algebraic sum of all the moments of the external forces on one side of any given point in the beam. If the moments are computed about several points, it will be found that the maximum moment occurs at the point where the shear is zero, or at the center of the uniformly loaded beam. The *maximum moment* must be considered in the design of beams.

Safe Bending Stresses.—The safe stress in bending is given in pounds per square inch for the material considered. A table of safe stresses is given on page 362. A member subjected to bending stresses is in tension in the lower part of the body, and in compression on the upper side where the load is applied. The line through which there is neither compression or tension is called the neutral axis, and is taken as being at the center of a rectangular beam.

Internal Resisting Stresses.—The strength of a beam depends upon both the material and the shape. The resistance to external forces must be sufficient to provide equilibrium. The resisting moment is equal to the sum of the moments of all forces acting about the neutral axis. The safe resisting moment is equal to the section modulus times the safe fiber stress for the material.

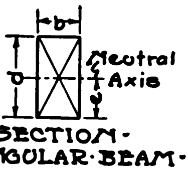


FIG. 316.

Design of Beams.—For equilibrium the maximum bending moment must be equal to the internal stresses. Therefore, $M = Qs$, where M is the maximum moment, Q is the section modulus, and s is the safe stress per square inch of material. For rectangular beams, $Q = \frac{1}{6}bd^2$. The values

for M and s for various materials and loadings are given in Chapter XXXVIII.

Value of Maximum Moment.—The value of the greatest bending moment is determined by taking the moments about the point where the shear is zero. This is in the center of a beam with uniform load. If W is used to represent the total load, L the span, and the moments added algebriacally, the following results will be secured:

$M = \frac{1}{8}WL$ for simple beam, distributed load;
$M = \frac{1}{4}WL$ for simple beam, load at center;
$M = \frac{1}{2}WL$ for cantilever beam, uniform distributed load;
$M = \ WL$ for cantilever beam, load at end.

Columns.—The columns or posts used in farm buildings are of wood, cast iron, and steel, filled with concrete. In Chapter XXXVIII will be found figures for the safe load in tons for various lengths, materials, and sizes. The external load on any column can be figured quite accurately, by including the weight of the construction, dead load, and wind load or live load likely to be placed on any given support. The design of columns will not be discussed here. If the reader is further interested he is referred to a handbook on the building trades or to a text book on Mechanics.

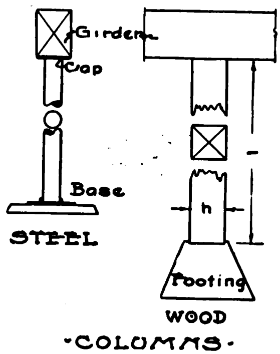


FIG. 317.

Roof Trusses.—The technical student should understand how to determine the various loads on roof trusses and the design of the more common types of roof trusses. The subject is covered fully in textbooks of Engineering Mechanics, and the reader is referred to them for a full discussion. The non-technical reader will usually wish to follow standard practice in roof construction.

CHAPTER XXXI

BUILDING CODES AND FIRE PREVENTION

THE fire loss in the United States amounts to hundreds of millions annually. The number of buildings destroyed in one year would be equivalent to a built-up street extending from New York to Chicago. Loss by fire, even though covered by insurance, represents an economic loss, requiring time and money to replace. Loss of valuable live-stock by fire is a serious problem, and the loss in human life cannot be replaced.

Fire loss is due, in a majority of cases, to cheap or flimsy construction, carelessness with matches, accumulation of waste about the buildings, defective chimneys, and lightning. The various building commissions, insurance commissions and state fire marshals are constantly working to reduce the fire hazard.

Fire prevention on the farm is especially important, since the means for protection are usually inadequate, and prevention is better than the cure in this case.

Building Codes.—The State or municipal building code is a set of local laws pertaining to the construction of buildings within the jurisdiction of the territory governed. The building codes govern the sanitary conditions, limit fire districts, establish a standard of workmanship consistent with the best practice, and promote character, permanence, and esthetic principles in building construction. Although the building code is not enforceable outside the territory to which it applies, the codes usually follow the line of best practice, and the study of State or local codes will afford much information of value in a study of farm buildings. Such a code can usually be secured by addressing the State Building Commission of the State in which the reader resides. The National Board of Fire Underwriters of New York have

adopted codes or rules for the installation of wiring, heating, and lightning protection, chimney construction, storage of fuel oils, etc., which should be followed to the letter. The codes are the result of investigation over the entire country and a study of the causes of fires. A material reduction of insurance premiums is often secured, if the code suggestions are followed.

Space does not permit of a full discussion of building codes. In cities and towns, the local laws must be followed. In the country it is desirable to follow the codes as nearly as possible, especially with regard to fire protection, sanitary conditions, and equipment and strength of materials.

Fire Protection on the Farm.—The prevention of loss by fire on the farm may be considered under the headings of fire protection, fire-resisting construction, lightning protection; and prevention by safe construction and carefulness.

Fire Protection.—A supply of water under pressure affords an excellent fire protection. The average farm is not within reach of outside fire protection, and a supply of water on the farm will often be the means of stopping the fire before it has gained headway. Small fire extinguishers filled with chemicals may be located in the garage, house, and barn, and a small blaze may be extinguished without having caused much damage. The location of buildings some distance apart may prevent the spread of the fire to more than one structure.

Fire-resisting Construction.—The term "fireproof" is often misused. A very few materials, including burnt clay, brick, concrete, and plaster, are fireproof. In any building the wood parts, furnishings, trim, etc., are combustible. Other materials are fire-resisting, but not absolutely fireproof.

The use of hollow tile and concrete in wall construction, concrete floors and steel equipment in the barns will reduce the fire hazard. Garages and smokehouses should be made as nearly complete as possible of masonry. Most of the fires from gasoline and oils, carelessness with matches, and small fires in the yard might be prevented by the use of masonry in the lower walls of the buildings.

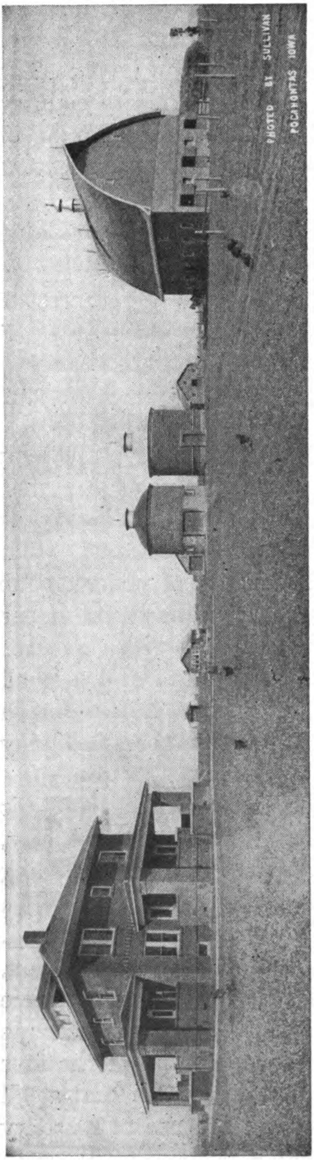


FIG. 318.—Permanent farm buildings.

Some attention has been given to the possibility of fireproofing the dairy and horse barn, because of the value of the stock. The complete masonry building is costly to build, and difficult of construction. A large loft filled with hay burns with an intense heat, which makes the use of steel frames or trusses ineffective for fireproofing. The authors believe that the best method of making the barn fire-resisting is to make the stable walls of concrete or hollow tile, and to use a reinforced loft floor. This would largely prevent the start of fires, and should the top of the structure burn, the lower masonry part would retard or stop the fire sufficiently so that the stock could be removed.

Lightning Protection.—Figures on lightning losses which have been compiled show that the annual property loss from lightning is about 8 million dollars, and the losses are chiefly in rural districts. More than 500 persons are killed by lightning each year. The protection of buildings from lightning losses consists of lightning-rod equipment, of the correct type and properly installed. Many fraudulent operations and inefficient outfits sold have often preju-

diced owners against the lightning rod. Honest manufacturers and reliable equipment have demonstrated the value of protection. Investigations show that very few buildings properly rodded are damaged by lightning. In many States the rods appear to be more than 95 per cent efficient.

Lightning-rod Equipment.—The important parts of the rod equipment are the air terminals, rods or conductors, and the ground connections. Air terminals should be attached to all high points such as cupolas, spires, and chimneys, the distance between terminals along ridges not exceeding 25 feet. Two rods or paths from each terminal are preferable. The rods for best construction are twisted wire cable, or star-section iron rod, and need not be insulated from the building. The ground is made by extending the iron or copper rod 8 or 10 feet into the ground to permanently moist soil.

Safe Construction and Carefulness.—One of the most common sources of fire is the defective chimney. There should be only one smokepipe entering each flue. Brick should not be laid on edge, but flat. Terra-cotta tile flue linings, protected by brick, should be used. Chimneys are supported by a masonry foundation. No wood framing should be built into the chimney, and all headers or openings should be framed so the wood members do not come within 2 inches of the chimney. Smokepipes should enter the chimney horizontally, and through a tight metal or tile thimble. The chimney should be built at least 2 feet above the ridge of the roof.

Fires in the outbuildings can be traced usually to carelessness with matches, gasoline, or engines using steam or explosive fuels. Gasoline engines or steam boilers should not be operated in the barn. Open flames must be kept away from the barn as far as possible. Oily rags and waste in the garage and shop should be kept covered in metal cans, and disposed of frequently. Waste saturated with linseed oil will ignite by spontaneous combustion in a short time. Spontaneous combustion in damp or green hay, or in damp coal is a frequent cause of fires.

CHAPTER XXXII

CONTRACTS AND SPECIFICATIONS

In order properly to perform a piece of work in which several persons are interested, it is necessary to have some agreement, either verbal, written, or implied, relating to the nature of the work, materials used, workmanship, and the compensation.

In building work the contract, covering the compensation, time of completion, nature of the work, etc., constitutes only a part of the contract. The blue-print plans and the written specifications are usually made a part of the contract. Printed contract forms for building are available at the office of every architect and builder. These contracts comply with the legal requirements, and are a standard form.

On small buildings it may be possible to include on the drawings sufficient notes and explanations to specify the kind, grade, and quality of material and workmanship. For houses or barns, the plans are accompanied by a typewritten set of specifications. The specifications cover the general conditions, including the various items in the scope of the work, method of handling the contract, and the quality and kind of material and the grade of workmanship expected on the job. The specific statements follow the general specifications, covering the material and methods for each subdivision of the work or each part of the construction.

Method of Writing Specifications.—The writer of specifications should have a definite order of writing. The general clauses should be written first. The writer should be familiar with the general practices in construction in the locality, local codes, and customs. He must also be familiar with the plans and should know, in a general way, the comparative cost of the

building. Local sizes and available grades of material should be determined. The specification writer should know the methods of handling work such as concrete work, painting, plumbing, etc.

Specifications should cover the items of material and workmanship completely, in clear, concise, and definite wording. No points should be left to the imagination, and no clause should allow for a difference of opinion between interested parties.

General Conditions

This section of the specifications covers all points of a general nature necessary for the submission of the bids and the completion of the work in a satisfactory manner. Each of the common sections of the general conditions will be mentioned briefly in the following paragraphs.

Bids.—This part includes a statement of where, when, and how the bids are to be received, when opened, possible alternates, right of rejection, amount of deposit, and bond.

Time of Completion.—Date on which work is to be completed, and forfeit for non-completion on specified date.

Rights Reserved.—The right to reject inferior materials, to waive proposals, or to require the removal of objectionable workmen from the job, is included in many specifications.

Local Laws.—This part of the specification calls the attention of the bidder to local rules and requirements that must be met, and laws regarding liens for labor and material payments.

Payments.—State laws regulate payments for work done; or a mutual understanding regarding payment should be specified, to protect builder and owner.

Insurance.—Owner or contractor pays for insurance on building during the course of construction. Usually the builder carries the insurance until the work is accepted.

Names.—The owner is the person or firm for which the work is done; the architect is the professional designer who prepares the plans, and acts as agent for the owner in letting the contract, and in handling the building project. The super-

intendent looks after the interests of the owner and architect. The contractor is responsible for doing the work.

Delays.—Every effort should be made to avoid delays.

Guarantee.—Some parts of the building, such as the roof, plumbing, heating plant, etc., should be guaranteed against defects for a certain length of time.

Similar or Equal.—The use of this term makes it possible to use one of several kinds of material or equipment, providing the minimum requirements are met.

Drawings.—The specifications refer to definite sets of drawings and to certain sheets. Each sheet and drawing should be numbered, so there will be no question as to the reference.

Details.—There may be need of full-size or large scale drawings for special construction. Details take precedent over the working drawings in case of discrepancy.

Alterations.—Alterations or extras should be cared for in the specifications, to avoid unreasonable charges. All changes should be agreed to in writing, and so far as possible, unit prices established for extra work.

Workmanship.—The quality of the work should be maintained, and no contractor should employ unskilled or disreputable workmen.

Materials.—All materials for the completion of the work should be included, and the kind and quality should be mentioned. The grades, such as "No. 1," or "clear" should be definitely mentioned.

Rejected Materials.—All materials rejected by the superintendent should be removed from the premises at once.

Protection.—Enclosed openings, protection for the public, danger signals, and protection of trees and planting are a part of the contract.

Damage.—The contractor should be made liable for damage or injury to workmen incurred by carelessness or neglect on his part.

Scaffolding.—The contractor must furnish all scaffolding, machinery, and equipment for handling the work.

Temporary Heat.—Heat to dry plastering, protect pipes, or to cure green concrete should be furnished by the contractor.

Cleaning Up.—The contractor should clean the premises and leave the building broom clean before the work is accepted.

Temporary Privy.—The contractor should provide toilet facilities for the men, keeping it in a sanitary condition.

Surveys and Levels.—This service should be provided by the contractor, unless otherwise stated.

Water.—The contractor should provide water for the needs of the construction.

Site.—The contractor is responsible for following local conditions and laws regarding the building, and should visit the site before bidding

Specification by Sections

Frequently the separate parts of the work are sublet, or let directly to specialty contractors. In each case the separate contractors are bound by the general conditions, and in the case of subcontractors, the general contractor is responsible for the satisfactory completion of the work so let.

All divisions of the contract, whether handled by one or several men, should be in harmony with the general conditions, and equal quality of work should be done throughout. The several special contractors should work to best advantage with each other and each contractor should see that his work is done at the logical time, with the least possible interference to the rapid construction.

The specifications are divided in much the same way that the building is divided in the construction, and in the order that the estimates are made. (See next chapter.)

Excavation.—This section covers the setting of corners and batter boards, removal and care of top soil and subsoil, excavation for trenches and drains, and the back filling and final grading.

Foundation.—This includes the testing and storage of cement, securing of the sand and coarse aggregate, proportion-

ing, mixing, placing, reinforcing, and finishing of the concrete. All points as to the quality, methods, and care should be definitely covered.

Concrete Floor.—The mixture, manner of laying, courses, slopes, and finish are included in the specifications.

Masonry.—This should include the specifications for all masonry outside the foundation and floors. Brick, chimneys, stone, masonry trim, mortars, etc., should be mentioned.

Carpentry.—All rough lumber, the cutting, nailing, fitting in place, grades, and quality are included in the section on carpentry.

Millwork.—This includes all materials and parts not made on the job. Finish lumber, windows, doors, frames, and outside trim should be specified.

Roof.—The type and kind as well as the quality of the roofing and possibly the trade name are included in this section.

Hardware.—Both the rough, or builder's hardware, and the finish hardware are included. The finish, quality, and pattern should be mentioned. In some cases the owner buys the hardware needed for trim, and the contractor sets it in place.

Painting and Glazing.—Paints, oils, tints, and the mixing and application are covered. The manner of fixing glass in the frame is also mentioned.

Lath and Plaster.—Lath includes the kind and manner of breaking joints and applying. Setting of grounds, and the kind of plaster, number of coats, and the application are included.

Wiring.—Switches, insulation, circuits, signals, outlets, size of wire, soldering, and the fixtures should be specified.

Plumbing.—The rough plumbing should be covered as to size, kind, and quality. Connections, supply, outlets, and cleanouts are indicated. The name, size, and finish of the finish plumbing are also covered.

Heating.—The location of boiler or furnace, kind of conductors, radiators or registers, sizes, and the complete layout and guarantee of the system is necessary in the heating specification.

Suggestions.—No sample specifications are included here for the reason that each building requires separate specifications, and copying is not advocated. If each of the above points are covered in a definite manner, with clear wording as to the kinds, and quality of material and workmanship, the results should be satisfactory. The reader can secure a stock set of specifications from any architect or builder for reference. It must be remembered, however, that there are points about each building that are not covered in stock specifications.

Contracts.—The contract is a legal form, and the average reader can acquire only a general understanding of the contract, by a study of contracts in effect. Laws govern contracts in most States, and standard forms, which are fair and legally binding, may be secured.

The architect's drawings and the written specifications are a part of the building contract. In general, the contract specifies the duties of each party, together with their responsibility and the amount and manner of payment.

CHAPTER XXXIII

COST ESTIMATING

THE cost of the building is the most interesting and one of the most difficult questions that confronts the prospective builder. The student should not attempt to estimate costs without knowing all of the conditions affecting the cost.

Conditions Affecting Costs.—The cost of the same type of structure will vary greatly with local and national conditions. Companies furnishing plans for different sections of the country usually refuse to estimate the cost, unless they are fully familiar with conditions where the building is to be constructed. The season of the year is important because the contractor usually has plenty of work in the spring and in the fall. In slack seasons he may be willing to reduce his profit to keep men and machinery busy. Winter work involves lost time, artificial heat, and protection to the work, which tends to increase the cost. In localities where little building is being done the cost will be lower, as a rule, for the contractors are not busy. Freight rates and trucking differ with the locality and length of haul. Carpenter's wages vary within large limits in different sections of the county. Lumber, cement, brick, and millwork vary with the scarcity of the product and the distance from the factory. The type of construction, efficiency of the builder, and overhead charges tend to vary the cost of construction.

Methods of Estimating.—The two general methods of estimating costs are known as the approximate and accurate methods. The object of the approximate method is to give the owner some idea of the amount of money he will need to have available for the work. It is by no means accurate, and must be used with caution. The accurate method takes into

account each item of overhead, material, and labor. The accurate method is the only one that should be followed by the student or contractor.

Estimating by Cubing.—This is the most convenient and the most accurate of the approximations. The contents of the building are determined, in cubic feet, and the result multiplied by a unit price. The outside dimensions of the building, and the distance from the basement or ground floor line to the average height of the roof, are used to figure the cubage. The unit price per cubic foot is based on other accurate prices for buildings of a similar type and in the same locality. Comparison with a large number of similar buildings will afford a more accurate unit than general figures based on a few buildings.

The cubic foot price for good frame dwellings is given in Kidder's "Pocketbook" as 10 cents per cubic foot, and the price was quite accurate for the time the book was published. In 1917 the cubic foot price in the Central States was around 17 cents per cubic foot, while in 1920 the same type of structure would cost between 25 and 40 cents.

Estimating by the Square.—In some cases it is more convenient to estimate by the unit of area. One hundred square feet may furnish a fair estimate of the cost of a store, armory, school, or large barn. This method is not so accurate as the cubic method. For small work such as lathing, plastering, cement floors, and shingles, the price may be based on the square yard unit, as the work is so nearly similar in different cases that the average cost may be used as a basis for an accurate estimate.

Estimating by Accommodation Units.—Instead of the volume or area unit the cost may be averaged for each unit of accommodation, or for each animal or stall in a barn, or for each room or person.

Accurate Estimating—Since the accurate estimate includes all factors which affect the cost, and specifies the exact amount of material, and a close estimate of the labor, it should be used in all cases as a basis for contracts, and as a guide to the probable cost of the building. The accurate estimate includes a material list, labor estimate and overhead charges, including

cartage, interest, depreciation, replacement, lost time, protection, and the contractor's profit.

Methods.—Before beginning an estimate, the reader should investigate the following factors:

Local prices for lumber and millwork.
Carpenter's and mason's wages.
Availability and cost of common labor.
Distance of haul.
Seasonal conditions.
Labor and market conditions.

After studying the above general conditions, the plans and specifications of the building should be carefully studied. The plans, elevations, and details should be visualized and special construction noted. It may be well to place all views of the building on a table or wall where they will be visible to the estimator. The specifications state the quality of workmanship, grades of material, and construction methods. The specifications as well as the drawings form a part of the contract, and should be followed carefully.

Legal restrictions, building codes and permits should be attended to when the estimating is being done. Insurance, protection, and safeguards should be figured in the cost.

Besides local prices and general information, the estimator should have a handbook containing "reminders," listing the possible points to be covered, tables of board measure, methods of construction, etc.

Order of Estimating.—The same order should be followed in estimating as in the construction of the building. The same order should be followed each time, to avoid the possibility of omissions. The following order is suggested:

1. Excavation and grading.
2. Masonry.
3. Rough lumber.
4. Millwork.
5. Plastering.

6. Plumbing.
7. Hardware.
8. Painting.
9. Lighting fixtures.

Under each of these heads the quantities, unit prices, labor, rate, and totals should be listed. It is very important that each item be placed under its proper heading and so labeled that it can be quickly referred to. This will facilitate checking, or tracing errors and will be valuable in future estimating. In Part V of this text will be found tables of materials and quantities that will be of assistance in estimating.

Excavation.—The cubic yard is the unit of excavation. To determine the amount, multiply the length, width and depth of the excavation in feet, and divide by 27. The excavation for dwellings is usually larger 1 foot each way, than the foundation. Excavation includes the removal of dirt for the necessary drains and trenches. The filling and grading are a part of the excavation contract. The top and subsoil are usually piled separately. The cost will vary with the character of the soil, depth of cut, manner of removing dirt and the amount of moisture. The average price per yard is 35 to 40 cents, for team work. The dirt can often be sold to other parties for filling purposes.

Masonry.—This division includes footings, foundations, chimneys, fireplaces, areaways, steps, walks, and floors of masonry construction. The usual divisions of the masonry work are stone, brick, hollow tile, mortar, and concrete. No allowance is ordinarily made for openings, as there is no saving for small openings. Corners are measured in each wall, or doubled.

Stone is measured by the perch, cubic yard, or ton. Only a small amount of stone is used in farm buildings.

Brickwork is measured by the thousand brick, or by the cubic foot, allowing twenty-one bricks per cubic foot. There should be an allowance of fifty bricks per thousand for waste. The grades usually used are common, for chimneys and backing;

face brick for exposed work, and special brick for decorations and fireplaces.

Hollow building tile are used largely in farm construction in place of brick, and are purchased by the thousand. A common size is 5 by 8 by 12 inches. Laid to form a 5-inch wall, one and one-half tile are required for each square foot of wall. If an 8-inch wall is made, there will be two tile per square foot. Hollow tile are laid up more rapidly than brick, and use about the same amount of mortar.

Mortar joints for brick vary from $\frac{1}{4}$ to $\frac{3}{8}$ inch, and $\frac{1}{2}$ to $\frac{5}{8}$ for hollow tile. One thousand common brick require about 14 cubic feet of mortar while about 55 cubic feet of mortar are required for 1000 hollow tile. Lime mortar is composed of 1 part lime to 3 parts sand, and a lime cement mortar is 1 part cement, 3 parts sand and 10 per cent by volume of lime putty.

Concrete costs include the price of cement, sand, gravel, forms, labor and reinforcing. Cement is sold in bags of 94 pounds, or in barrels of four bags each. Sand and gravel are priced by the cubic yard, at the pit, and freight and cartage must be added. From the tables of quantities given in Chapter XXXVII, the amounts of each ingredient can be determined for the mixture to be used. The volume of concrete necessary is figured in cubic yards or in cubic feet, and the aggregates determined. Reinforcing steel is specified in the plans and is priced by the pound.

The cost of forms may be reduced by using the form lumber in the superstructure, the amount of form lumber being determined in the same manner as the rough lumber. Contractors often use steel forms. The labor for concrete is a variable item. Four men and a power mixer should make 30 yards of concrete in a ten-hour day. Hand mixing requires more time.

Rough Lumber.—The items included in the rough carpentry are the framework or skeleton of the building, sheathing, roof covering and siding. The most important problem of the carpentry work is the " bill of material," or material list. The bill should specify the number of pieces, size, length, grade, kind of material, its use, number of board feet and the unit price and

total. The following example shows how the lumber should be listed:

10 pieces,	2×6	12′ 0″ long,	No. 1,	fir,	studding,	120 bd. ft.	@	$ 7.20
50 pieces,	2×12	16′ 0″ long,	No. 1,	y. p.	joist,	1600 bd. ft.	@	$104.00
Total								$111.20

In making up the material bill, it is best to start with the sills, and continue in much the same order as the construction work is to be done. Lumber is priced by the 1000 board feet, or in some cases by the piece. The standard sizes for the locality should be determined, and the order confined to stock lengths and sizes so far as possible. Lumber waste due to dressing and waste in sawing should be considered, and extra material ordered.

Millwork.—The millwork includes all of the inside finish, stairs, railings, moldings, windows and doors and all parts of the carpentry work not included in the rough lumber. The use of stock sizes and shapes, as listed by the millwork company, should be carried out as far as possible, as there is an extra charge for special sizes, ranging from 10 to 50 per cent higher than the cost of stock sizes. Practically all of the material can be found by securing catalogues and stock list from the millwork company nearest at hand.

Moldings, railing, quarter round, and trim are sold by the lineal foot. Complete trim for windows and doors is sometimes listed ready fitted. Windows are specified by giving the kind of window, width, length, number of lights, and how divided. Doors are listed, giving the width, height, and thickness, also the number of panels and the material and construction required.

Plastering.—The price for plastering is made on the basis of cost per square yard. The contract price may include lath, labor, and material. The entire area of the inside walls, including the ceiling, is figured, with no allowance for ordinary openings. An extra charge is made for high ceilings, small surfaces, and arches and curves. Keene's Cement plaster for kitchens

and bathrooms costs more than straight work. One hundred square yards of plaster, with patent plaster, will require about 9 bags of plaster, $3\frac{1}{2}$ bags of lime, $\frac{1}{2}$ barrel of plaster of Paris, and and a small amount of sand. One hundred square yards of lathing will require 1400 lath, and a fair laborer will lath that amount in one day.

Plumbing.—The rough plumbing includes soil pipes, drains, vents and traps. Water tank, pipes, fittings, and connections should be included in the contract. The septic tank should be included in the plumbing contract. The prices are quoted by the foot or by the piece, and a complete bill should be made from the plans. The finish plumbing includes bath, kitchen, and laundry fixtures. The price should provide for a good grade of enameled-iron plumbing. The plumbing work should be done by an experienced plumber, and prices should be secured for the job complete.

Hardware.—The rough hardware includes nails, flashing, gutters, and all tinwork on the house or barn. Door and window hardware should be selected by the owner, and prices secured from the dealer for the grade required. Hardware for the other farm buildings includes barn equipment, stalls, ventilators, hog house fixtures, etc. This material should all be selected by the owner, and installed by the contractor.

Painting.—Painting is measured by the square yard, and no deductions made for openings. One gallon of priming paint will cover 50 square yards of new work. One gallon of paint will cover about 40 square yards on the second and third coats. A good painter can do 100 yards of priming in a day, and 80 yards of second and third coat work. Inside finish and floor paints and varnishes vary so greatly that accurate information for all cases cannot be attempted here.

Lighting Fixtures.—The lighting fixtures and wiring should also be selected by the owner. For farm lighting plants the wire must be heavier than for the 100-volt city current. The average price for rough wiring is about \$1.25 per outlet. The cost of fixtures may vary within a considerable range according to quality.

Other Items.—The estimator will need to include screens, walks, heating plant, water system and like items in many plans.

Overhead Costs.—In making up the estimate of a building it must be kept in mind that there are many other items aside from labor and material that affect the cost. The contractor, established in business, must have interest on his investment, depreciation, insurance, office expense, and a return for the lost time of men. This expense is proportioned according to the isize of the job and the time required for the construction. This item does not necessarily increase the cost to the owner, as the increased efficiency of the contractor should offset this expense. If the work is done by day labor, or by the owner, a charge comparable to the overhead cost should be added to care for the cost of tools, extras, and a possible inefficiency. The charge for extras should be placed at about 10 per cent of the estimated cost.

Profit.—The contractor is entitled to a profit for the service and management supplied by him. The amount of profit varies with labor and material conditions, season, etc. The amount will range from 10 per cent on the large job, to 25 or 30 per cent on the small building. There are several ways of figuring profit. The most common method is a fixed sum, or lump sum, fixed by the contractor, when he makes the bid. Another method is the cost plus percentage, in which the contractor agrees to take a percentage of 10 to 15 per cent of the actual cost to compensate for the service rendered. The cost plus a fixed sum is a method favored by many.

Competitive Bids.—In many cases the owner will prefer to give the work to a certain contractor, because of his qualifications for carrying out the work. If several men are to bid on a job, there should be several sets of plans and specifications, for the use of the bidders. If the contract covers well-written specifications and complete plans, the owner will be reasonably safe in accepting the lowest bid. It must be kept in mind, however, that the higher price of one man may be made up by better workmanship, and a higher skill in building. The same competitive method of securing material bids may be followed.

Farm Building Costs.—The farmer should place a reasonable valuation on his services for hauling, excavating, and farm labor in the construction. The actual cash cost of farm buildings may be reduced considerably below the estimate if the farmer furnishes teams for hauling, board for laborers, and aids in the work of building.

The authors believe that many of the smaller structures shown in this book may be built at a low cash cost by the regular farm labor. This applies especially to small hog houses, feeding equipment, and sheds, on which the carpenter or contractor would not care to bid.

CHAPTER XXXIV

PLAN DRAWING

THE ability to read and understand drawings and blue prints is a necessary accomplishment if one is interested in farm buildings to any extent. The ability to draw plans or make working drawings is valuable to the student, builder, or farmer. Much of the value of the study of buildings lies in the working out of plans, and no course of study is complete without a portion of the time being devoted to drawing. There are several excellent books on the subject of drawing, and only a few brief suggestions will be given here to guide the reader in applying the principles to farm buildings.

Material for Drawing.—Complete plans require full equipment of drafting tools for best results, while simple sketch plans may be drawn with simply a rule and a pencil. For best results a reasonably complete outfit is necessary, and the following tools are recommended:

Drawing board.
T-square.
45 and 30–60° triangles.
Thumb tacks.
Architect's scale.
Drawing pencils, hard and medium.
Pencil eraser.
Waterproof ink.
Lettering pens.
Tracing paper or drawing paper.
Set of instruments, including ruling pen, combination compass and divider.

With good care a set of tools will last many years, and good quality tools should be purchased. A substantial, good quality set of tools may be purchased for $10 to $12.

Selection, Use and Care of Equipment.—The drawing board should be of soft wood, preferably poplar, basswood, or white pine, and should have at least one side perfectly straight and true. The best size is about 21 by 32 inches, the construction being such that it will not warp.

The T-square should have at least a 30-inch blade. The best squares are made of hardwood, such as maple, and edged with celluloid. The T-square should always be placed with the head against the left side of the board, and operated with the left hand. It is used for drawing horizontal lines, and to support the triangles in making vertical or diagonal lines. Lines are drawn along the upper edge of the square, from left to right. Only the left-hand side of the board should be used to guide the T-square.

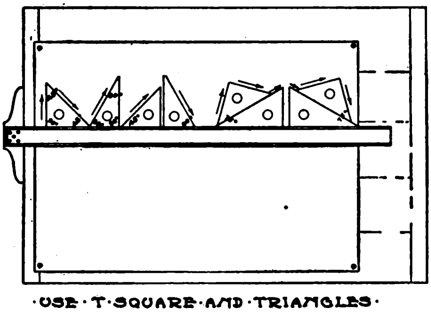


FIG. 319.—Drawing board with triangles and tee square.

Triangles are made of celluloid, and the two sizes mentioned above are the only ones necessary for ordinary work. Special lettering triangles, and large triangles are used for special work. The triangles are used for making vertical lines and lines at common angles, and are rested on the edge of the T-square to keep them squared with the work.

The architect's scale has the usual division of 12 inches to the foot, which is further divided into quarters, eighths, and sixteenths. Other divisions on the scale are $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, and 1 inch divisions, part of which are further subdivided into twelve parts each, for convenience. These fractional parts of the inch are used to represent 1 foot on the drawing. Beginners are often

inclined to reduce the scale of the plan by working with the regular divisions on the rule. A little study of the architect's scale will show its value.

Drawing pencils are graded from 6B, or very soft leads, to 6H, or very hard. The soft pencils make a heavy line but smear easily. HB is the best grade for sketching, and H or 2H is good for use on tracing papers. For careful work on drawing paper which is to be traced with ink the 4H is suitable. Pencils should be well sharpened to a long point, and kept sharp with a fine file or sandpaper.

Drawing ink should be of good quality, special India drawing ink, such as Higgins' Waterproof. The bottle must be kept corked at all times, except while filling the pen. Pens are not dipped into the bottle, but are inked by applying a small quantity of ink by means of the quill attached to the cork.

The ruling pen is always used in connection with the T-square and triangles. It is moved in the direction in which one would naturally write, and the nibs are kept parallel with the guide. Extremely fine lines should not be attempted.

The compass, with ink or pencil attachment, is of course used for curves and circles. The dividers are used to transfer measurements from one place to another, or for dividing a given space into an equal number of parts. All drawing instruments should be kept clean and dry, and should be carefully handled if accurate work is to be done.

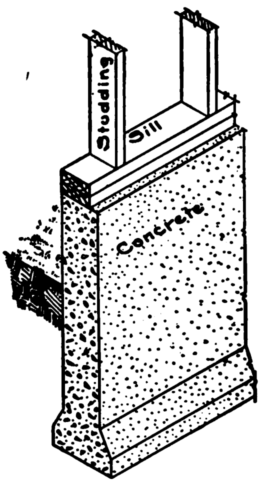
Drawing Paper.—Drawings in pencil which are to be traced and made permanent are usually made on a white or cream-colored heavy drawing paper. If the drawing is to supply only a few sets of blue prints, it may be made on tracing paper, a thin tough paper from which the prints may be made direct. Tracing cloth is for permanent drawings, and is a linen cloth treated with a starch preparation to make it semi-transparent. The best blue prints are made from cloth tracings.

Scales.—The usual working drawing is made to a scale of $\frac{1}{4}$ inch to the foot, and represented as $\frac{1}{4}'' = 1'\ 0''$. Large buildings are made to a scale of $\frac{1}{8}'' = 1'\ 0''$. These two scales are easily handled by the carpenter, as his rule is divided into

quarters and eighths. One inch on the carpenter's rule is equal to 4 or 8 feet. An odd scale such as $\frac{3}{8}'' = 1'\ 0''$ should rarely be used. Detail drawings are for the purpose of explaining the special, or complicated parts of the structure, and are made at a scale of $\frac{3}{4}''$ or $1''$ to $1'\ 0''$. Some few details are made full size. The working drawings when drawn to a small scale do not permit of complete drawings of all windows, doors, etc., and conventional symbols are used to represent them on the plans.

Kinds of Drawings.—The most important kinds of drawings in farm building work are the perspective, pictorial, and working drawings. Perspective drawing shows the building or object in the same manner that it appears to the eye. The value is to show how the finished building will look. The perspective is of no value as a guide to construction, and since it is difficult to construct, no discussion will be given here.

Isometric Drawing.—The principal pictorial drawings are the oblique and the isometric, both of which are widely used to illustrate bulletins, text books and charts. The isometric shows the whole object in one view, and as compared with the perspective, it gives a rather distorted view.



·ISOMETRIC·DRAWING

FIG. 320.—An isometric drawing.

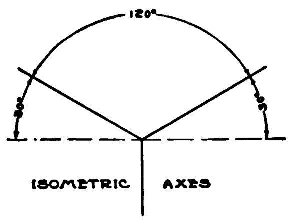


FIG. 321.

In plan drawing, there is only one view of the object shown. In the isometric drawing there are three axes, at angles 120°

apart—a vertical axis, and two axes 30° from the horizontal form the base of the isometric drawing. All vertical lines of the figure are parallel to the vertical axis, while horizontal lines normally parallel to the paper are made parallel to one of the 30° axes, and perpendicular lines are parallel to the other 30° line. Thus three views, as the top, front, and side of any object, may be shown in one drawing. All measurements are taken along the line of the isometric axes. Lines not parallel to the isometric axes are drawn by locating a point on the line, then measuring along the axes to locate the point on the isometric drawing. Lines drawn through the point so located give a true isometric line.

Oblique drawings are similar to isometric in construction. Instead of three axes 120° apart, one axis is made vertical, one horizontal, and the third at 30°. Fig. 71 is an example of the oblique drawing.

Working Drawings.—The working drawings of the structure are the ones of most importance to the builder. They consist of the various views of the structure, drawn to a workable scale, and include lines, dimensions, notes, and lettering. A small simple building may require only one or two views, while the barn or house should include several views and details. The more complete the drawings the less chance there is of slighting the work.

Working drawings include the following:

Floor plan for each floor of building.
Basement plan.
Roof plan if necessary.
Four elevations.
Cross-section.
End framing.
Longitudinal or side elevation of framing.
Interior elevation if necessary.
Details of construction.

The floor plan is a horizontal section through the wall, taken to include as many features of walls, openings, and equip-

ment as possible. The framing sections and elevations locate the framing members, show heights, sizes, and methods of construction. The elevations locate window and door openings, show covering material, roof pitches, exterior treatment and, to some extent, indicate the appearance of the finished building.

In general, the details should show all special construction and parts unfamiliar to the builder. Details may vary with the importance of the work and the skill of the builder. As a rule,

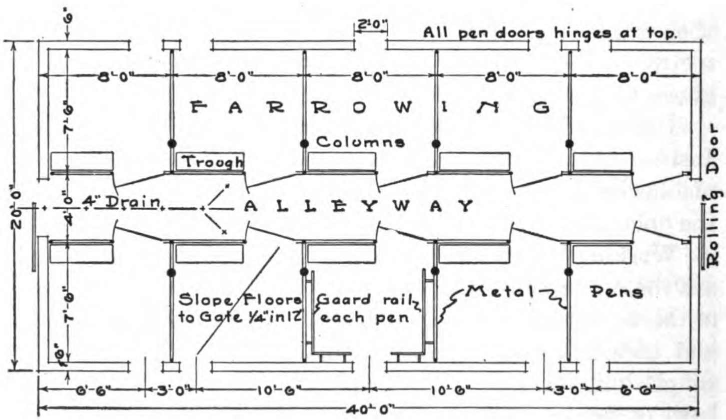


FIG. 322.

the more complete the details the more likely that the methods of good practice will be followed.

Method of Drawing.—Aside from the mechanical procedure of handling the drafting tools, the designer of farm buildings should have in mind several suggestions which apply in particular to farm buildings. A careful study should be made to determine the best arrangement, construction, and equipment of the building. The purpose for which it is intended will have some influence on the plan. The essentials of sanitation, appearance, economy of construction, and convenience should be fully considered before the plan is drawn.

The second step is to sketch the floor plan of the building to

secure the best plan and as many advantages as possible. It may be necessary to sketch the plan several times before a satisfactory arrangement is secured. Time will be saved if dimensions and sizes are noted on the sketch plan.

The entire plan should be drawn in pencil before any part

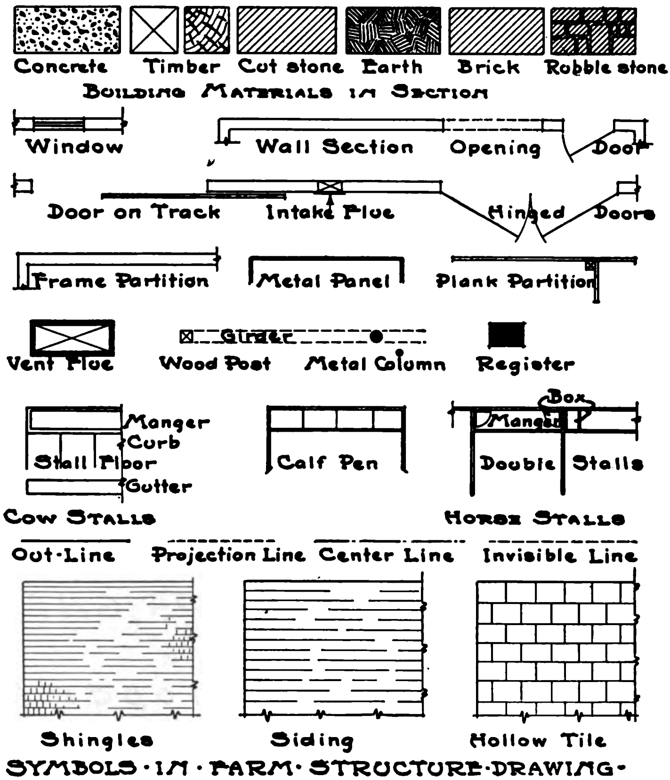


Fig. 323.

of it is inked so that the plans may be made to correspond in every particular. After the floor plans are completed, the framing sections, elevations, and details are drawn. When the plans have been approved they may be inked and blue printed. Details are sometimes furnished as the work pro-

gresses, though in most cases the best method is to furnish complete plans and details before the contract is let.

Dimensions.—The figures on the plans are of greatest importance. Very little should be left to the imagination of the builder, and figures should be noted rather than to depend on the scale. Dimensions should include outside width, length, spacing of openings, sizes of openings, sizes of rooms, spacing of equipment, sizes of material, and, in fact, all data necessary to the construction of the building.

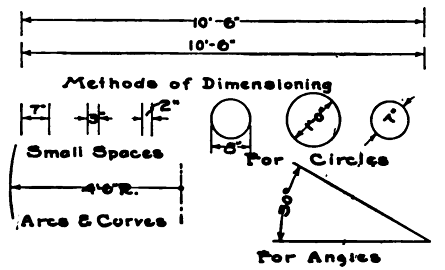


FIG. 324.

Figures should be rather large, plain, and easy to read.

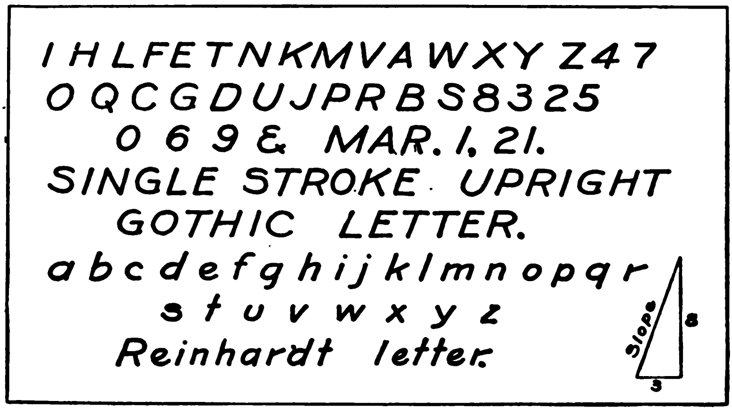


FIG. 325.—Reinhardt inclined lettering.

Arrow heads should clearly indicate from what points the figures are to be taken. Series of figures should be carried across the drawing in a line, rather than be placed at various points.

Lettering.—Letters should be made of a size in proportion to the space available, and the importance of the detail or note. Architectural lettering is less formal than lettering on machine drawing, and there is more room for artistic expression. The

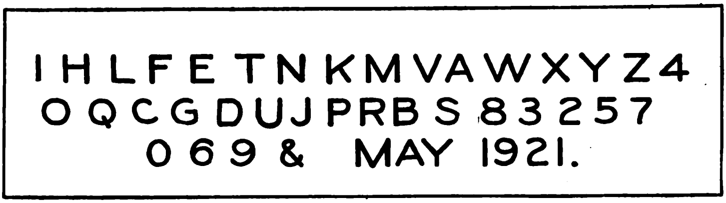


Fig. 326.—Vertical lettering.

average draftsman should adhere strictly to a plain, simple, readable style of lettering. Good lettering is of great imporance and should not be slighted. Constant practice is necessary for proficiency. Capital letters are desirable for the important lettering on plans. Each sheet should have a suit-

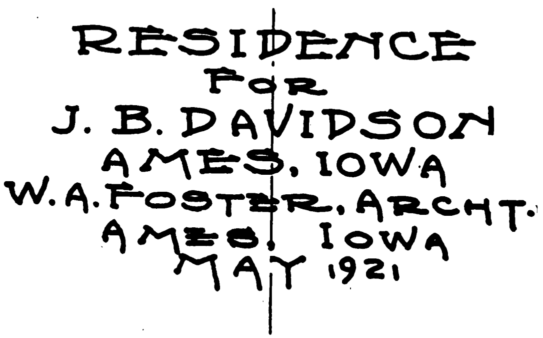


Fig. 327.—Title layout.

able title, showing the number of the sheet, number of the drawing, name of owner and draftsman, and the date and scale.

About Original Work.—Student draftsmen should avoid copying. Each plan is a special plan, and if too much copying is done the results may not be satisfactory. The student should

refer to good completed drawings for information as to methods and construction details. Care should be taken, however, to preserve the originality of the drawing at hand. The drawings in this text, although primarily for the purpose of illustration, show methods and practices common to good construction. Reference to the illustrations will show various methods of drafting, manner of handling the various parts of the construction, and plan arrangement.

No list of problems for practice is given in the text. The authors have found that the best results are secured if the student works out plans for buildings in which he is particularly interested. One of the best problems to work out is the complete plan of a farm barn, possibly for the student's home farm, or one in which he is interested.

CHAPTER XXXV

RAFTER FRAMING AND CUTTING

Roof framing is considered one of the most difficult parts of construction. The carpenter solves the problems of cutting and framing by means of the steel square. The student or draftsman uses applied geometry. In order that both methods may be understood, the simpler problems of roof framing will be discussed here.

Types of Roofs.—The roofs found on most farm buildings may be grouped into four general classes of shed, gable, hip, and gambrel. The framing of the monitor and "sawtooth" roofs present the same problems as the above-mentioned classes.

The shed or lean-to roof has a single slope, and the problem of rafter cutting is confined to the one slope and pitch. The gable roof has two equal slopes, which meet at the center of the building to form a ridge, and has a gable at each end. The hip roof slopes from all four walls to the center, meeting in a point or a short ridge. Sometimes the hip roof has a deck at the top, instead of a ridge. The gambrel roof has already been discussed. This type of roof has two slopes in each side of the roof for which the rafters and braces must be cut.

Common Terms in Roof Construction.—Some of the terms used in this discussion were defined in Chapter IX. The reader should also be familiar with the following definitions:

Ridge.—The intersection of the two slopes of a roof, usually in the center of the building.

Span.—The horizontal distance between walls or plates on which the rafters rest.

Run.—The horizontal distance spanned by a rafter. In the gable roof the run of any rafter is equal to one-half the span.

Rise.—The vertical distance from wall or plate to the top of rafter, or to the ridge.

Pitch.—The ratio between the rise and the span, expressed numerically as $\frac{1}{2}$, $\frac{1}{4}$, etc., and denotes the steepness of the roof. Pitch $= \frac{\text{Rise}}{\text{Span}} = \frac{\text{Rise}}{2 \times \text{Run}}$. For example, a rise of 6 feet on a span of 24 feet is expressed as $\frac{6}{24}$ or $\frac{1}{4}$.

Rafter.—The sloping structural member of the roof frame.

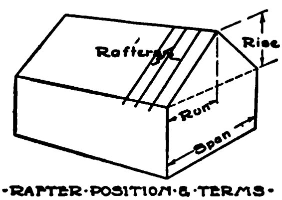


FIG. 328.—Rafter position and terms.

Collar Beam.—A short horizontal tie to strengthen the rafters at the ridge.

Hip Rafter.—Diagonal rafter in the hip roof, which runs from the corner to the ridge.

Jack Rafter.—Short rafters extending from the plate to the hip rafter, in the hip roof frame.

Rafter Cutting.—The sloping rafter must be cut in such shape that when placed in position in the frame it will rest squarely and securely on the wall or plate at the bottom and meet the opposite rafter or ridge pole squarely at the top. The cut at the bottom is called the seat cut, and the top cut on the rafter is known as the ridge, or plumb cut. If the rafter sets entirely on the wall, the seat cut is horizontal. If the end of the rafter projects beyond the plate to form the lookout, the rafter must be notched at the plate, and the seat cut will have both vertical or plumb cut and horizontal cut.

The object of using the steel square in cutting rafters is to determine the length and the shape of the ridge and seat cuts.

Determining the Cuts.—Properly to determine the cuts on the rafter it is necessary to find the rise and run of the rafter. This is found by referring to the plans. The run is scaled on the blade of the steel square, and the rise is scaled on the tongue of the square, the reason for which is shown by the illustration. If the rafter were placed in a sloping position as it would be in the roof, and the steel square placed so the blade is along the line of the plate, and the tongue is in line with the ridge, it will

be found that a line drawn along the blade and tongue would be horizontal and vertical, respectively. The usual method is to lay off 12 inches along the blade, representing 1 foot of run, and the number of inches on the tongue depends on the slope of the roof, as 6 inches when the pitch is $\frac{1}{4}$. The upper edge of the rafter or a chalked center line is used as a work line. The square is held as shown in Fig. 331, with the figures for run and rise on the work line. A line scribed along the blade will be parallel to the seat or horizontal cut, and a line scribed along the tongue will be plumb when the rafter is placed in position.

If the lower end of the rafter projects, the end is usually cut parallel to the ridge cut. The vertical part of the seat cut will also be parallel to the ridge cut. If the above points are kept in mind it will be possible to cut rafters for any given pitch by means of the steel square.

Determining the Length.—As a rule only the pitch of the rafter is given, and it is necessary to determine the exact length before cutting. There are two methods of finding the length, which may be designated as the analytical method and the practical, or carpenter's method. Both will be discussed briefly.

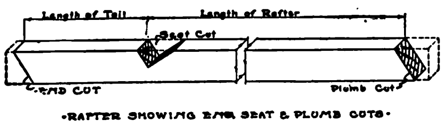


Fig. 329.—Rafter Cuts.

Analytical Method.—It will be noted that the run and rise of any rafter form two sides of a triangle, of which the rafter line is the third side or hypotenuse. By geometrical rule, the sum of the squares of the two sides is equal to the square of the hypotenuse. Therefore, the square root of the run squared plus the rise squared will equal the length of the rafter, from the plate to the ridge. After the length of the rafter has been marked off on the stock, the square is used to determine the cut. The plumb cut should be made near one end of the piece. The square is then moved to the other end of the laid-out length, and a plumb line is marked through this end. Next the square is moved to a position such that a line scribed along the blade will intersect the plumb line. If the rafter is to seat

entirely on the plate, the stock is sawed off at the horizontal cut. If the rafter is to be notched, the depth of the notch may be regulated by the position of the square when the horizontal line is scribed. The overhang or show end of the rafter is

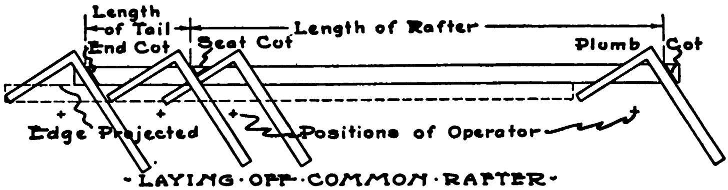


FIG. 330.—Common rafter layout, calculated.

marked for a plumb cut, at a distance from the plate as desired, or as shown by the plans.

Carpenter's Method.—This method begins with the laying out of the ridge cut, near one end of the stock, after the pitch is known. In the first method described, 12 inches was taken as the run, and the rise was taken as a proportional part of 1 foot. Therefore, if the steel square is laid on the rafter stock in one

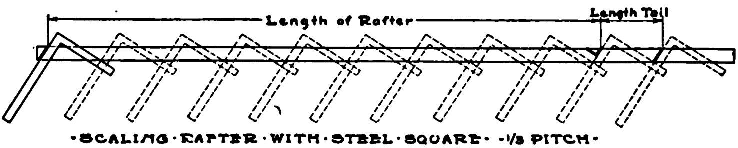


FIG. 331.—Common rafter layout, scaling—carpenter's methods.

position, and lines are scribed on both outside edges of the square, and sawed out, the result would be a rafter whose run is 1 foot long, but with the correct cuts. It follows that if the single setting of the square gave the length of rafter proportional to 1 foot of run, it is only necessary to set the square along the piece, beginning at the ridge cut, as many times as there are feet of run in the rafter.

After the square has been placed a sufficient number of times to lay off the length, vertical and horizontal lines through

the point found will give the seat cut, and the end, or heel cut, is found as before.

The carpenter's method is more likely to be in error, since there are several settings of the square. It is simpler, however, to handle than the theoretical method. After one rafter has been laid out and cut, the master pattern will serve by which to cut all other similar rafters. The beginner should put the first pair in place, however, to see that no error has been made. Care must be taken to have all cuts in correct relation to one another, in order that they will fit properly into the roof frame.

Hip-roof Framing.—The rafter cutting described above applies to the simpler styles of gable, shed and monitor roofs. The parts of the hip roof are more difficult and complicated and will not be discussed here. If the reader is especially interested in the hip roof, he should consult a treatise on roof framing, or on the steel square. Hip and valley rafters are those framing the sloping intersection of two roof slopes. The length is equal to the square root of the sum of the three edges of the cube, or imaginary box, of which the rafter is the diagonal. The jack rafters vary in length, usually by even increments. The exact lengths and cuts are not of sufficient importance in farm buildings to justify consideration here.

Gambrel-roof Framing.—The pitches, lengths, and construction of the gambrel roof are fully discussed in Chapter X. The ridge cut of the upper rafters is cut the same as that for the common rafter. In the Shawver frame the lower end of the upper rafter is cut square with the stock. In the braced rafter frame the cut may be made to bisect the angle between the upper and lower rafters. Since the lower rafters in this framing usually rest on the plate, the seat cut is full horizontal. If the Shawver frame is used, the opposite end of the lower rafter is cut at 60° with the horizontal, to fit against the purlin. If there is no purlin, the rafter end is cut to fit the upper rafter. The lookout on the braced rafter or Shawver frame is usually cut at 45°.

Other Uses of Steel Squares.—The steel square is used for many other purposes on the construction job, and is one of the most useful of all tools for the carpenter. Volumes have

been written on the use of the square, and the reader is referred to one of them for further information.

Siding in the lower gable ends may be cut by using the same setting of the square as for the horizontal cut, since the angle of the horizontal siding cut is 90°, rafter angle. A setting of equal figures on the tongue and blade will give an angle of 45° with the work line.

The use of the steel square in framing is not confined to the framing of the larger structures about the farm, but is valuable in determining the cuts in the building of small hog houses, poultry coops, feeders, and such structures.

CHAPTER XXXVI

WEIGHTS, MEASURES, AND FORMULAS

Linear Measure

12	inches	= 1 foot
3	feet	= 1 yard
5½	yards	= 1 rod
320	rods	= 1 mile

Square Measure

144	square inches	= 1 square foot
9	square feet	= 1 square yard
30¼	square yards	= 1 square rod
160	square rods	= 1 acre
640	acres	= 1 square mile, or 1 section

Cubic Measure

1728	cubic inches	= 1 cubic foot
27	cubic feet	= 1 cubic yard
128	cubic feet	= 1 cord

Avoirdupois Weight

16	drams	= 1 ounce
16	ounces	= 1 pound
2000	pounds	= 1 ton

Liquid Measure

4	gills	= 1 pint
2	pints	= 1 quart
4	quarts	= 1 gallon

Dry Measure

2	pints	= 1 quart
8	quarts	= 1 peck
4	pecks	= 1 bushel

Geometrical Formulas.—To find the circumference of a circle: Multiply the given diameter by 3.1416.

To find the diameter of a circle: Divide the given circumference by 3.1416, or multiply by .3183.

To find the radius of a circle: Multiply the circumference by .1591, or divide the diameter by 2.

To find the area of a circle: Square the radius, and multiply by 3.1416, or square the diameter, and multiply by 3.1416 and divide by 4.

To find the area of a circular ring: Subtract the area of the inner circle from the area of the outer.

To find the area of a triangle: Multiply the base by one-half the altitude.

To find the area of a square, rectangle, or parallelogram of any shape, multiply the base by the altitude.

To find the area of a trapezoid: Multiply the altitude by one-half the sum of the parallel sides.

DECIMAL EQUIVALENTS FOR COMMON FRACTIONS

Fraction	Decimal	Fraction	Decimal
1/16	.0625	9/16	.5625
⅛	.125	⅝	.625
3/16	.1875	11/16	.6875
¼	.25	¾	.75
5/16	.3125	13/16	.8125
⅜	.375	⅞	.875
7/16	.4375	15/16	.9375
½	.5	1	1.

Metric Measure.—There are several important advantages in the use of the metric system, as compared with the English system, the most important of which is the ease of handling the mathematical operations by the decimal. The English system of weights and measures is so well established in the United States that the metric system is not likely to displace it in the near future. The metric system is used largely for scientific work in this country, although it is the standard measure in many countries. In farm buildings work the use is limited to

work done for South American or European countries, either in plan work or in farm building equipment.

The unit of linear measure is the meter (39.37 inches), and the other units are found by taking decimal parts or multiples of the meter. The centimeter is $\frac{1}{100}$ meter long. The millimeter is $\frac{1}{1000}$ of 1 meter. The kilometer is 1000 meters.

The unit of volume measure is the liter (1.0567 quarts) for liquids, and the same unit is used for dry measure, and equals .908 quart dry measure. The unit of weight is the gram (15.432 grains), and is the weight of 1 centimeter of water. The kilogram is equal to 2.20462 pounds.

Metric Equivalents.—The following table shows the value of the more common English units, in the metric system:

English Unit	Metric Equivalent
1 inch	2.54 centimeters
1 foot	.3048 meter
1 yard	.9144 meter
1 sq. yd.	.836 square meter
1 acre	.4047 hectare
1 mile	1.60935 kilometers
1 gallon	3.7854 liters
1 pound	.4536 kilogram

Miscellaneous Data.—There are 63,360 inches, 5280 feet, 1760 yards, 320 rods in one mile.

One acre contains 43,560 square feet, or 4840 square yards, and is about 209 feet square.

One cubic foot contains 7.48 gallons, or .408 bushel.

One cubic foot of water weighs 62.4 pounds.

One gallon of water weighs 8.36 pounds.

There are 231 cubic inches in 1 gallon.

One bushel of small grain contains $1\frac{1}{4}$ cubic feet, approximately. One bushel of ear corn contains $2\frac{1}{2}$ cubic feet.

One horsepower = 550 foot-pounds per second = 33,000 foot-pounds per minute = 746 watts = 760 kilogram-meters per second.

CHAPTER XXXVII

REFERENCE TABLES FOR FARM BUILDING DESIGN

THE handbook data given in the following pages are those most frequently needed by the student and builder. For complete information and enlarged tables, the reader is referred to the standard handbook of the building trades, "Architect's and Builder's Pocketbook," by Kidder.

Bearing Power of Soils.—Farm buildings should be set with the footings below the frost line, and on firm soil. The farm house, barn, and silo should show a very small amount of settlement. The footings recommended in the text will probably not give more than 1 ton per square foot pressure on the soil. The bearing power of soil is given in the following table:

Material	Tons per Square Foot
Rock, sandstone or limestone...	20 to 30
Dry clay on thick beds.........	4 to 6
Moderately dry clay...........	2 to 4
Soft clay.....................	1 to 2
Clean dry sand................	2 to 4
Solid and dry earth...........	2 to 4

Tables for Proportioning Concrete.—The following figures are adapted from tables by the Portland Cement Association. The first table shows the resulting volume from given proportions, by volume, of cement, sand, and gravel. The second table gives the amount of each ingredient required to produce 1 cubic yard of concrete.

MATERIALS

Mixture	Cement, Bags	Sand, Cu.Ft.	Gravel, Cu.Ft.	Resulting Volume, Cu.Ft.
1 : 1 : ½	1	1.5	..	1.75
1 : 2	1	2.0	..	2.10
1 : 3	1	3.0	..	2.82
1 : 2 : 3	1	2.0	3.0	3.90
1 : 2 : 4	1	2.0	4.0	4.50
1 : 2½ : 5	1	2.5	5.0	5.45

MATERIAL FOR ONE CUBIC YARD

Mixture	Quantity of Materials		
	Cement, Bags	Sand, Cu.Ft.	Gravel, Cu.Ft.
1 : 1½	15.48	23.2	....
1 : 2	12.84	25.6	....
1 : 3	9.56	28.6	....
1 : 2 : 3	6.96	14.0	20.8
1 : 2 : 4	6.04	12.2	24.0
1 : 2½ : 5	4.96	12.4	24.8

Weight of Materials Stored in Farm Buildings.—For the calculation of the various members of the structure for strength it is necessary to know the weights of various materials commonly stored about the farm or used in the building. The table following gives the weight per cubic foot, for convenience, and the figures do not represent the weight per bag, bushel, or other unit;

Material	Weight, Cu.Ft.	Material	Weight, Cu.Ft
Alfalfa seed	48	Hay, baled	25
Apples	40	Hay, loose	4
Barley	40	Hemlock	26
Brick, common	125	Ice	57
Cast iron	480	Lime	53
Cement	100	Limestone	164
Clover seed	48	Maple	49
Coal, soft, lump	54	Oats	27
Concrete	150	Potatoes	48
Cornmeal	40	Red Oak	46
Cottonseed	27	Sand	100
Cypress	29	Shelled corn	47
Earth, rammed	100	Southern pine	38
Fir	32	Water	62.4
Gravel	120	White Oak	48

Pounds per Bushel.—The following table of pounds per bushel is based on the Iowa law, which corresponds closely to the legal specifications in other States, and to the standards of the Federal Government. A bushel measure contains approximately $1\frac{1}{4}$ cubic feet of volume.

Material	Legal Weight, Bushel	Material	Legal Weight, Bushel
Alfalfa seed	60	Corn, shelled	56
Apples	48	Cornmeal	48
Barley	48	Millet seed	50
Beans	60	Oats	32
Bluegrass seed	14	Onions	52
Bran	20	Potatoes	60
Buckwheat	48	Rye	56
Cherries	40	Timothy seed	45
Clover seed	60	Wheat	60
Corn, ear	60 to 80		

WEIGHT OF WOOD PER BOARD FOOT

Kind of Wood	Weight, Pounds
Cedar	3.0
Cypress	3.1
Douglas fir	2.7
Hemlock	2.1
Oak	4.1
Pine, short leaf	2.6
Pine, white	2.3
Pine, yellow, Georgia	3.2

Weight of Roof Covering.—The design of roof framing and trusses must take into account the weight of the covering including sheathing, shingles, tile, etc. The average weight of the material used in roofing is shown in the following table:

Material	Weight per Square Foot, Pounds
Pine sheathing	3.0
Shingles, wood	2.0
Slate	4.5
Corrugated iron	2.25
Asbestos shingles	4.5
Asphalt roofing	2.5
Tiles, plain	18.0

Table of Board Measure.—A short rule for finding the number of board feet in a piece of lumber is as follows: Multiply the width of the piece in inches by the thickness in inches, divide by 12, and multiply by the length of the piece in feet. For instance, to find the number of board feet in a 2 by 6, 16 feet long: $2 \times 6 = 12$. Dividing by 12 equals 1, times $16 = 16$ board feet. After a small amount of practice the work can be done rapidly. The table on the following page gives the board feet in the common sizes of lumber. The total number of feet is found by multiplying the number of pieces by the figure in the table. Lumber is usually sold by the thousand feet.

TABLE OF BOARD MEASURE

Size, Inches	Length of Piece in Feet								
	8	10	12	14	16	18	20	22	24
1×3	2	2½	3	3½	4	4½	5	5½	6
1×4	2⅔	3⅓	4	4⅔	5⅓	6	6⅔	7⅓	8
1×6	4	5	6	7	8	9	10	11	12
1×8	5⅓	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
1×10	6⅔	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
1×12	8	10	12	14	16	18	20	22	24
2×4	5⅓	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2×6	8	10	12	14	16	18	20	22	24
2×8	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2×10	13⅓	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2×12	16	20	24	28	32	36	40	44	48
2×14	18⅔	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
3×6	12	15	18	21	24	27	30	33	36
3×8	16	20	24	28	32	36	40	44	48
3×10	20	25	30	35	40	45	50	55	60
3×12	24	30	36	42	48	54	60	66	72
3×14	28	35	42	49	56	63	70	77	84
4×4	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4×6	16	20	24	28	32	36	40	44	48
4×8	21⅓	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4×10	26⅔	33⅓	40	46⅔	53⅓	60	66⅔	77⅓	80
4×12	32	40	48	56	64	72	80	88	96
6×6	24	32	36	42	48	54	60	66	72
6×8	32	40	48	56	64	72	80	88	96
6×10	40	50	60	70	80	90	100	110	120
6×12	48	60	72	84	96	108	120	132	144
8×8	42⅔	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8×10	53⅓	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8×12	74	80	96	112	128	144	160	176	192
10×10	66⅔	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10×12	80	100	120	140	160	180	200	220	240
12×12	96	120	144	168	192	216	240	264	288

Lumber Waste.—Dressed lumber, according to the standard rules for sawing and grading, does not contain full width of material when delivered to the job. Some further waste is due to sawing and fitting the lumber into the building. To cover the usual losses, it is necessary to figure in excess of the amount actually needed. The following percentage of increase over the nominal estimates are made:

Material	Sizes, Inches	Add to Estimate
Matched lumber........	2½ to 3	One-third
Matched lumber........	4	One-fourth
Matched lumber........	6	One-sixth
Shiplap................	6 to 8	One-fifth
Shiplap................	10	One-tenth
Drop siding............	......	One-fifth
Lap-siding.............	......	One-third
Framing lumber........	......	One-fifth

Shingles Required.—Shingles average 4 inches wide, 250 to the bundle, or four bundles per thousand. A square of roof, or 100 square feet is the unit of roof surface. The figures given below are based on the number of shingles per square for different exposures:

Exposure, Inches	Number of Shingles
4	900
4½	800
5	720
6	600

NAILS REQUIRED FOR CARPENTRY WORK

Material	Nails in Pounds	Size "d"
1000 shingles	3.5	3
1000 shingles	5	4
Lath, per M	8	3
Bridging per M lineal feet	26	8
Sheathing per M	20	8
Sheathing per M	25	10
Studding per M	15	20
Joists per M	15	20
Flooring per M	20	8 to 10 finish

Paint Required.—Ready-mixed paint will cover about 250 square feet of surface two coats. One gallon of trim is required to each 5 gallons of body paint on average buildings. Creosote shingle stain will cover 150 square feet one coat if brushed on. Dipping requires 3 gallons of stain for each 1000 shingles treated. Flat paint on plaster walls will cover 200 square feet per gallon one coat. One pound of calcimine wall finish will cover 50 or more square feet, depending on the condition of the wall.

Labor Quantities.—The personal factor makes any estimate of labor quite unsatisfactory. The figures given here are those commonly considered as making a fair day's work, although it may be said that there are always unlooked for delays on every job.

One man will complete the following in eight hours:

500 board feet studding, joists or rafters.
500 feet sheathing.
500 board feet shiplap or matched lumber.
350 board feet 6-inch flooring.
350 feet siding.
1500 shingles.
1000 board feet barn boards.
7 doors, fit and hang.
80 square yards painting, smooth work.

Loads on Structures.—The loads on buildings that must be considered in the design may be classed as dead loads, wind and snow loads, and live loads. The dead load is made up of the weight of the material making up the building, and the material stored. The live load consists of moving bodies, people, or animals. The live load is twice as severe a strain on the building as the dead load.

Live Load.—The usual figures for live load are not especially adapted to farm structures; however, they show the effect of moving bodies, and must be considered in the design of strength of house-framing members.

Type of Structure	Load per Square Foot, Pounds
Crowded houses	80
Dwellings	50
Schools, churches, theaters	100
Dance halls	100
Warehouses	250

Wind and Snow Loads.—The snow load is not effective when the pitch of the roof is 45° or more. The maximum snow load is not likely to occur when the full wind load is acting. The following figures indicate the maximum effect of snow load on a $\frac{1}{4}$ pitch roof in different sections:

Locality	Maximum Allowance, Pounds per Sq.Ft.
Southern States	5
Central States	20
Rocky Mountain, and N. E.	25
Northwest States	30

Wind loads act at right angles to the surface of the roof. For velocities of less than 10 miles per hour the effect is negligible. A very high wind of 80 miles per hour will exert a

pressure of 30 pounds. For safe design, 40 pounds is taken as a maximum.

Safe Working Stresses in Bending.—The following figures are those commonly used as the safe stress per square inch in bending, from which to figure the size of beams, joists, or girders. Building codes of some cities specify the bending stresses to be used. The safe stress is taken at about one-tenth of the breaking load.

Material	Safe Stress, Pounds per Sq.In.
White oak..............	1200
Southern pine...........	1200
Cypress.................	800
Douglas fir.............	800
Hemlock.................	600

Beam Formulas.—A discussion of the design of beams has been given elsewhere in the text. The maximum external moment, or the moment due to the load applied depends on the manner of loading and the method of support. The figures below indicate the maximum moment in foot-pounds, and inch-pounds, for the beams commonly found in farm buildings:

W = total load, in pounds.
L = length of span in feet.
$L \times 12$ = inch pounds.

Kind of Beam	Manner of Loading	Maximum Moment.	
		Ft.Lbs.	In.Lbs.
Simple	Uniform distributed	$\frac{1}{8}$ WL	$\frac{3}{2}$ WL
Simple	Concentrated at center	$\frac{1}{4}$ WL	3 WL
Cantilever	Uniform Distributed	$\frac{1}{2}$ WL	6 WL
Cantilever	Concentrated at end	WL	12 WL

The internal resisting moment is usually figured in inch-pounds, in which case the maximum moment must also be taken in inch-pounds.

Safe Load for Beams.—The figures in the table below are given for ease of determining the correct size of beam for conditions commonly found in farm structures. The loading is for a simple beam, with uniform distributed load. The safe stress in bending is taken as 1200 for yellow pine, the most common framing material. Figures are given for a beam 1 inch wide. The formula used in the calculation is $\frac{bd^2s}{6}=\frac{1}{8}WL$. b is taken as 1 inch d or depth of beam is given, s is 1200, L is the span in feet, given, and $L\times 12$=inch-pounds. W or total safe load is the quantity shown in the body of the table:

Depth of Beam, Inches	Span in Feet					
	8	10	12	14	16	18
4	267	213	178	152	133	118
6	600	479	400	342	299	266
8	1067	851	710	608	531	474
10	1667	1333	1110	950	830	740
12	2400	1915	1598	1368	1195	1066
14	3267	2607	2176	1862	1626	1450

For beams wider than 1 inch, multiply the above figures by the width of the beam in inches. For load concentrated at the center divide the figures by 2. For oak beams use the same figures. For fir, use two-thirds of the above figures, and for hemlock use one-half.

Example.—Find the safe uniformly distributed load for a 2 by 12-inch, hemlock joist, span 12 feet. The above table shows 1598. For 2-inch width the safe load is 2×1598, or 3196. The safe stress for hemlock is 600, so the figure must then be divided by 2, leaving the actual figure in the table of 1598 as the safe load.

Safe Load for Columns.—The load on columns consists of the weight of stored material, live load, and the weight of the material in the building. This load can be determined quite accurately. The following table based on figures by Kidder gives the safe load for yellow pine posts. Oak posts will support approximately the same load safely.

SAFE LOAD IN TONS FOR YELLOW PINE POSTS

Size of Post, Inches	Length in Feet			
	8	10	12	14
4×6	9.1	8.4	7.7	...
6×6	15.1	14.4	13.7	12.9
6×8	20.2	19.2	18.3	17.3
8×8	32.0	27.2	26.3	25.3
8×10	40.0	34.0	32.8	31.6
10×10	50.0	50.0	42.8	41.0

Steel Columns, Concrete Filled.—The use of steel columns in farm buildings makes it desirable to understand the capacity for loading in comparison with wood posts. The James Manufacturing Company furnished the following table, based on new steel tubes, filled with concrete at the factory:

Diameter of Post, Inches	Length of Feet				
	6	7	8	8½	9
3½	9.0	8.5	8.3	8.0	7.5
4½	14.0	13.5	13.0	12.7	12.5
5	20.25	20.0	19.5	19.25	19.0

INDEX